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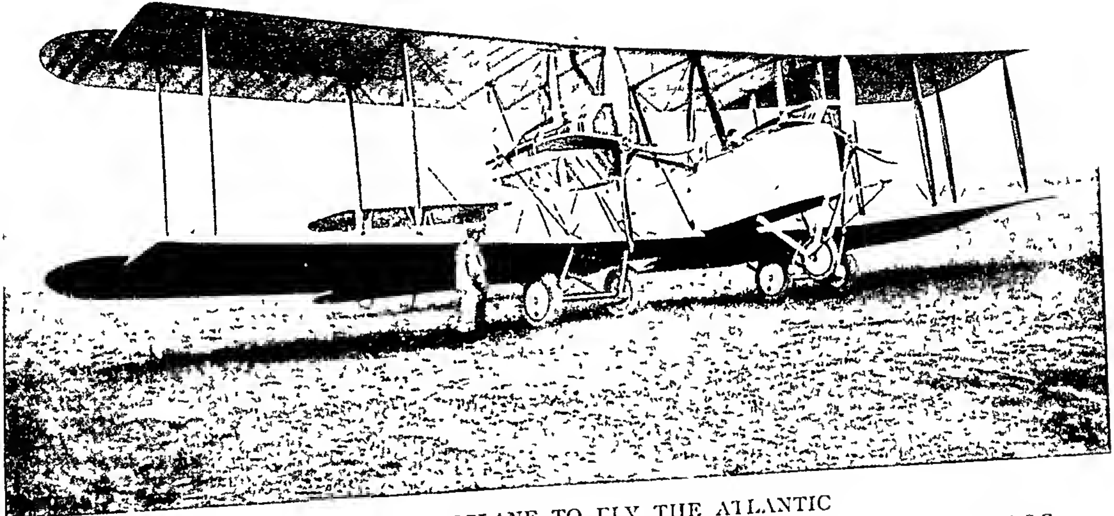

THE FIRST AEROPLANE TO FLY THE ATLANTIC

The first direct non stop flight across the Atlantic was accomplished on June 14–15, 1919, by two British aviators, Capt J Alcock, D S C (pilot), and Lieut. A. Whitten Brown (navigator), flying a Vickers-Vimy aeroplane The coast to coast flight of 1880 miles was made in less than 16 hours.

Chap VI

TRIUMPHS OF INVENTION

BY

CYRIL HALL
Author of "Conquests of Engineering"
"Wonders of Transport"
"Treasures of the Earth"
&c.

ILLUSTRATED BY THIRTY-TWO REPRODUCTIONS FROM PHOTOGRAPHS

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Prefatory Note

The present volume indicates the lines upon which the triumphs of invention have been won, and describes in detail those which are most striking.

The present is the age of invention, and one achievement follows another so rapidly that this generation is in danger of forfeiting the faculty of wonder. At the beginning of the nineteenth century Trevithick's clumsy steam carriage was so astonishing to a rural toll-keeper that he took it to be a manifestation of Satan himself; now every schoolboy accepts the miracle of Wireless as a matter of course.

One service which the present volume is qualified to perform is to remind the reader that many of the commonplaces of modern life would have seemed to his grandparents to belong to the realm of imagination and fantasy.

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Illustrations

TRIUMPHS OF INVENTION

CHAPTER I

A Great Inventor and his Work

The mental qualities of man, as we know him to-day, are many and various, differing as widely as his physical attributes. But once upon a time, so geologists tell us, he was a very humble creature, little superior to the beasts of the field and maintaining his existence among them by craft and cunning. Man would have been exterminated before he had properly evolved had it not been for his quality of inventiveness. He was the one creature—except the members of the ape and monkey family—which could throw; he was absolutely the one creature which could shape a weapon. Man being by nature a defenceless animal, he had to provide himself with some means of attack as strong as, or stronger than, the talons, beaks, and jaws of his enemies. The nails of his fingers and toes were flimsy and brittle, his

mouth was badly placed for biting, and it was not always possible to come to throttling terms. Thus for the sake of a bare existence did man develop his inventive instinct, until by reason of that instinct he mastered all the brutes with which he met, irrespective of size and strength.

It is a far cry from our half-naked ancestor, shaping a flint in the gloom of his skin wigwam, to the arsenal of to-day, where the most frightful and devastating of war machines are produced. But the two are united by a mighty chain, every link of which has been forged by some man's efforts, some man's tears and woe, and untiring devotion. To most inventors life proves a bitter, joyless thing, death coming either before recognition or just at the moment when success seems attainable. Yet we trust that they find their reward in the ultimate good that springs from their endeavours rather than in their own material advancement.

From the point of view of the writer of a book like this, the trouble is that there has been too much invention. By no possibility can space be found even for reference to the countless numbers of methods and devices which have brought modern life to its present pitch of comfort and efficiency. Still less can we mention the unsuccessful inventions, many of which have embodied ideas which, in the brains of men other than the originators, have developed into prosperous undertakings.

It must be borne in mind that few, if any, inventions

are the work of one man. In the great majority of cases an invention which is acclaimed to-day as the crowning triumph of Jones, is nothing more than an amplification of some idea evolved by Brown ten, twenty, or thirty years ago, and will itself be lost in the grand production of Robinson some fifty years hence.

Where, then, are we to start with our story, and —a question still more difficult to answer—where are we to end? The story of invention is as old as man himself, and begins where he begins, and yet there are those who affirm that the age of inventions opened with the last century. I am afraid there is nothing for it but to compromise; to include ancient history where it is necessary to explain the modern, and to exclude it where possible for the sake of brevity.

Perhaps we can hardly do better than to devote our first chapter to a short account of the life and accomplishments of him who has been aptly called "the Master of Modern Invention"—Thomas Alva Edison. To him already we owe so much, and we may with reason hope to owe him so much more, that he is well worthy of foremost place in the ranks of our inventors, even though the world was to a certain extent ready-made when he entered it. Chance or Providence led his steps into one particular path, and his own genius and energy found that path to be the one above all others which he desired to tread. Let us see how events fell out.

It may be encouraging to many of his youthful

disciples to learn that Edison did not get on well at school. In fact, he only stayed at school three months, for he was so much disturbed by overhearing the master describe him as "addled" that he left forthwith. His mother, who had been a school-teacher before her marriage, educated him herself. We read of Edison as a boy besieging with questions everyone with whom he came in contact. When at length the limit of endurance was reached, and he received "I don't know" for answer, he would retort: "Then why don't you know?" But though he was unpromising in ordinary class-work his power of absorbing knowledge was extraordinary. No subject seemed to be too abstruse for him, and with his mother's help he stored his brain with science, particularly those branches of science which relate to electricity.

At the age of twelve he considered it incumbent upon him to do something towards earning his living, and with that end in view he started selling papers on board the trains of the Grand Trunk Railway, running between Port Huron, where his home was, and Detroit. Selling papers, however, did not satisfy him. Becoming the proud possessor of a second-hand printing press, he set it up in his train and actually printed a little newspaper, which he called the *Weekly Herald*. His friends among the railway employees along the line would hand him items of news which arrived by telegraph at the various stations, and thus he was able to offer his subscribers advance news. He persuaded a friend to help him

with the selling of magazines and candy while he devoted his time to his printing. So matters continued for two or three years, and all might have gone well had he confined his activities to printing. Unfortunately he also attempted chemical experiments, and one day he set fire to the train. Little damage was done, but the irate conductor literally discharged him and all his belongings at the next station. Poor Edison was left sitting disconsolately among the ruins of his printing press and chemical apparatus, a sadder and a wiser boy. But, although his editorial days were over, Edison continued to sell sweets and papers on the train—"candy butcher" was his official rank—until an accident occurred which decided the future course of his life for him.

One of his stanchest friends among the railway men was Mr. Mackenzie, agent and telegraph operator at one of the stations passed through daily by Edison's train. This man took a deep interest in the enterprising, unusual boy, and the two often talked together in the intervals of their work. On one such occasion Edison was horrified to see that Mackenzie's little boy had toddled out on to the railway line, and was playing happily in the direct track of an express train. Quick as thought Edison flew to the rescue, and succeeded in snatching the child to safety as the train went thundering by. Mackenzie could think of no more acceptable reward than to offer to teach Edison telegraphy—an offer which was eagerly welcomed. For years Edison had been experiment-

ing with telegraphy, and had rigged up private lines between his own house and those of his friends, and the opportunity to work with a real apparatus was too alluring to be declined. In three months he had mastered the instrument, and set out to find a post for himself as telegraph operator.

Now the surprising thing is that Edison did not at the outset prove himself strikingly efficient at his job. His first position involved night work, and he started his duties when his brain was already wearied with the efforts he had exacted from it during the day. Consequently he lost his position for sleeping on duty. His next post he lost for experimenting on duty, and meantime allowing a train to pass although the line ahead was blocked. Another of his employers expelled him forcibly for dancing the "can-can" in office hours and smashing the instruments. So it went on, and Edison shifted about the country from one town to another, constantly gathering experience and becoming an astonishingly expert telegraphist. He also "invented" at this time his characteristic handwriting—very neat and plain and extraordinarily rapid, with which he could take down the fastest telegraph operator with perfect ease. But all the time he was drifting towards his jumping-off place—the appointment which was to bring him his first access of capital and first opportunity for development along his own lines.

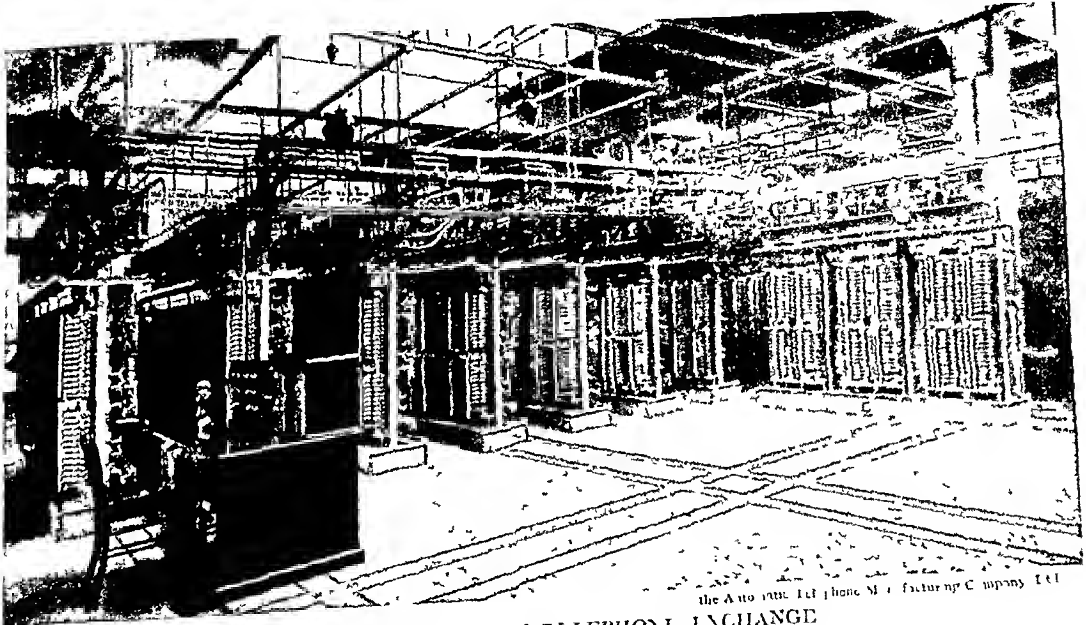
Edison's first invention, a "vote-recorder", was a total failure as a practical speculation, and led him

to make the following resolve: "There and then I made a vow that I would never invent anything which was not wanted, or which was not necessary to the community at large". But it only deepened his determination to produce something which should be "necessary", and for that reason he decided to leave the ranks of telegraph operators and strike out into some new walk of life. The first thing necessary seemed to be to get to New York; and at length, by slow stages, he arrived there, almost penniless.

He had no very distinct plans for earning a living, but Fortune favoured him. At that time indicating machines, or "tickers", were a novelty and not very reliable. Hundreds of brokerage offices in the city were provided with them, but they were constantly giving trouble. Edison's footsteps chanced to lead him up to the head office of the Law Gold Indicator, on just one morning when the machines were refusing to work, and the manager was being driven nearly frantic by the complaints and enquiries of his subscribers. Edison watched the futile efforts of the workmen for some little time, then he approached Mr. Law and told him he thought he could find the trouble. Mr. Law was willing enough for him to make the attempt, and in a minute or two Edison had set all the machines to work again. The cause of the mischief was in reality quite trivial, but had escaped the notice of the staff. Mr. Law, however, was so much struck by Edison's perspicacity that he forthwith

offered him the post of manager, at a salary of 300 dollars a month. This was untold wealth to Edison, who hitherto had kept body and soul together and provided himself with books and instruments on a wage that had never exceeded 75 dollars a month, and was often less.

At last he could realize his heart's desire. His work with the indicator company occupied him all day, but his evenings and his nights were his own, and these he devoted to labouring in a workshop which he speedily equipped for himself. With the assistance of a mechanic named Callahan he set himself to improve the "ticker", and to evolve from the existing instrument one which would "tick" with some semblance of regularity. For the perfected machine which ultimately he produced the company paid him the astonishing sum of 40,000 dollars. Overwhelmed by his good fortune, Edison pocketed the cheque and went out to consider what he should do with it. He had never had such a thing before, and after turning the matter over and over in his mind he took his cheque to the bank to be cashed. The cashier, however, complained that he did not know Edison, and refused to cash the cheque. Not quite understanding the position, Edison supposed that he had been hoaxed, and left the bank in a far different state of mind from the exaltation in which he had entered it. Happily for him, and probably for the world at large, he met a friend outside who promptly took him back to the bank and cleared the matter up.



By courtesy of the Automatic Telephone Manufacturing Company Ltd

THE LEEDS AUTOMATIC TELEPHONE EXCHANGE

To ring up on an automatic telephone a subscriber simply lifts the receiver off the hook and moves a pointer on a dial to the successive figures of the number required

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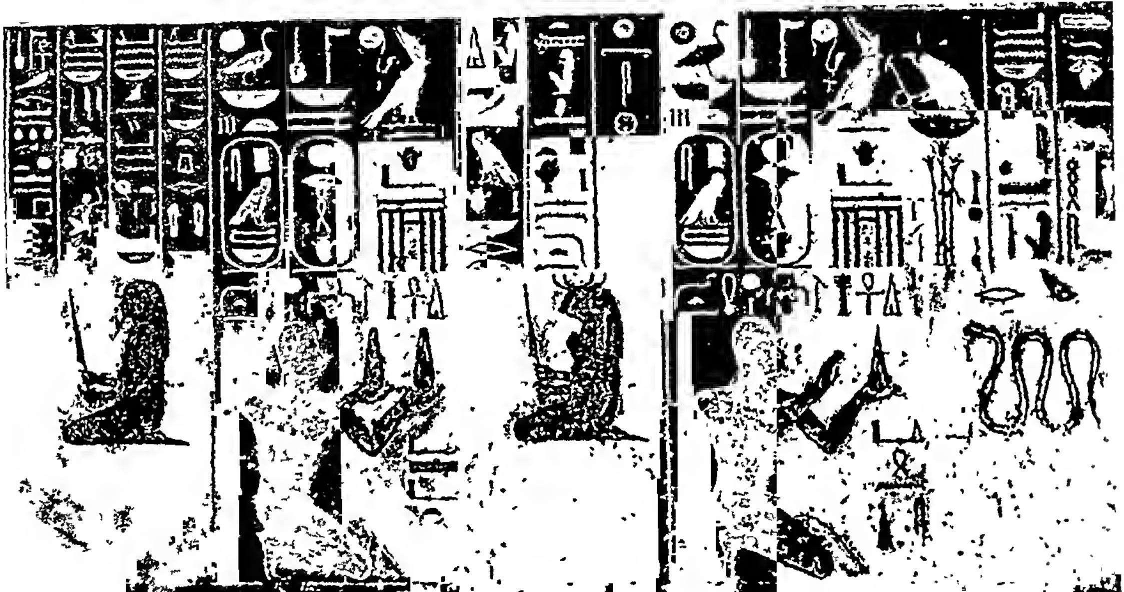

EGYPTIAN HIEROGLYPHICS

The Egyptian hieroglyphic system of writing was a form of picture writing which arose thousands of years before the Christian era. The inscription, of which a part is shown above, describes King Seti I, about 1366 B.C., offering to the god Amen Ra, who promises to give him "All good, beautiful, and pure things".

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Edison now had sufficient capital to enable him to devote himself to invention. Ideas flooded into his brain in constant succession, to be seized upon and perfected with incalculable speed. At first his efforts were directed principally towards the improvement of the telegraph. For this purpose he opened a factory at Newark, New Jersey, where he began to produce the wonderful instruments his genius had conceived. First of all appeared the duplex telegraph, whereby two messages could be sent simultaneously in opposite directions along one wire. This was followed by the quadruplex, and ultimately by the sextuple telegraph. The story of his struggles with the automatic telegraph is characteristic of his indomitable will and energy, and is well told by Charles Bachelor, Edison's chief assistant at that time, in Dickson's *Life of Edison*, in the following words:—

"In the development of the automatic telegraph it became necessary to have a solution which would give a chemically-prepared paper upon which the characters could be recorded at a speed greater than 200 words a minute. There were numerous solutions in French books, but none of them enabled him to exceed that rate. But he had invented a machine that would exceed it, and must have the paper to match the machine. I came in one night, and there sat Edison with a pile of chemistries and chemical books that were 5 feet high when they stood on the floor and laid one upon the other. He had ordered them from New York, London, and Paris. He studied them

night and day. He ate at his desk, and slept in his chair. In six weeks he had gone through the books, written a volume of abstracts, made two thousand experiments on the formulas, and had produced a solution (the only one in the world) which would do the very thing he wanted done—record over 200 words a minute on a wire 250 miles long. He ultimately succeeded in recording 3100 words a minute."

Every month Edison was adding to his reputation. The world watched him fascinated, as one after another his inventions came upon the market. On one occasion he was referred to publicly as "that young man in New Jersey who has made the path to the Patent Office hot with his footsteps". But he was soon to strike off in a new direction—one which was to lead him far upon untrodden paths.

On 15th February, 1876, occurred a coincidence which is probably unique in the histories of all Patent Offices. Two applications were filed for "transmitting vocal sounds telegraphically", one being from Alexander Graham Bell, and the other from Elisha Gray. Both were fundamentally the same, and two patents could not be granted. Investigation showed that Bell's application was filed a few hours before Gray's, and to him was given the patent. But his telephone was of no practical use, though it was acknowledged to be an interesting and instructive scientific toy. Few people believed in its possibilities, and he had great difficulty in finding enough money to float his company. While he was struggling against the ob-

stacles which beset the way of most inventors Bell heard that Edison had solved the problem of transmission by inventing the carbon telephone transmitter. Of course Bell saw that that was the very thing needed to make his telephone a success, but Edison refused to sell him the patent. Yet the transmitter by itself was of no use to Edison, and he could not devise a telephone which did not in some detail or other infringe Bell's patent. In the end, after troublesome litigation and delay, Edison sold his patent to Bell, and, in his own words, "quit the telephone business". But he still worked at adaptations and modifications of the original idea, producing numerous forms of telephonic transmission.

Not long after he had brought his carbon transmitter to perfection Edison took a holiday, from which he returned with his mind braced up and fresh for some new adventure. As it happened, the new adventure was put into his hands in the shape of an electric lamp, costly, faulty, and unsatisfactory. Immediately he focused a vision of a perfected electric lamp—of great lamps to light streets, little lamps for houses, of electric light carried all over a city or generated for isolated factories and dwelling-houses. Here is the story in his own words:—

"In 1878 I went down to see Professor Barker, at Philadelphia, and he showed me an arc lamp—the first I had seen. Then a little later I saw another—I think it was one of Brush's make—and the whole outfit, engine, dynamo, and one or two lamps, was

travelling round the country with a circus. At that time Wallace and Moses G. Farmer had succeeded in getting ten or fifteen lamps to burn together in a series, which was considered a very wonderful thing. It happened that at that time I was more or less at leisure, because I had just finished working on the carbon button telephone, and this electric-light idea took possession of me. It was easy to see what the thing needed — it wanted to be subdivided. The light was too bright and too big. What we wished for was little lights, and a distribution of them to people's houses in a manner similar to gas. Governor P. Lowry thought perhaps I could succeed in solving the problem, and he raised a little money and formed the Edison Electric Light Company. The way we worked was that I got a certain sum of money a week and employed a certain number of men, and we went ahead to see what we could do.

"We soon saw that the subdivision never could be accomplished unless each light was independent of every other. Now it was plain enough that they could not burn in series. Hence they must burn in multiple arc. It was with this conviction that I started. I was fired with the idea of the incandescent lamp, as opposed to the arc lamp, so I went to work and got some very fine platinum wire drawn. Experiment with this, however, resulted in failure, and then we tried mixing in with the platinum about 10 per cent of iridium, but we could not force that high enough without melting it. After that came a

lot of experimenting—covering the wire with oxide of cerium and a number of other things.

"Then I got a great idea. I took a cylinder of zirconia and wound about a hundred feet of the fine platinum wire on it coated with magnesia. What I was after was getting a high-resistance lamp, and I made one that way that worked up to 40 ohms. But the oxide developed the phenomena now familiar to electricians, and the lamp short-circuited itself. After that we went fishing around and trying all sorts of shapes and things to make a filament that would stand. We tried silicon, and boron, and a lot of things that I have forgotten now. The funny part of it was that I never thought in those days that a carbon filament would answer, because a fine hair of carbon was so sensitive to oxidation. Finally, I thought I would try it, because we had got very high vacua and good conditions for it.

"Well, we sent out and bought some cotton thread, carbonized it, and made the first filament. We had already managed to get pretty high vacua, and we thought, maybe, the filament would be stable. We built the lamp and turned on the current. It lit up, and in the first few breathless minutes we measured its resistance quickly, and found it was 275 ohms—all we wanted. Then we sat down and looked at that lamp. We wanted to see how long it would burn. The problem was solved—if the filament would last. The day was—let me see—21st October, 1879. We sat and looked, and the lamp continued to burn, and

the longer it burned the more fascinated we were. None of us could go to bed, and there was no sleep for any of us for forty hours. We sat and just watched it with anxiety growing into elation. It lasted about forty-five hours, and then I said: 'If it will burn that number of hours now, I know I can make it burn a hundred.' We saw that carbon was what we wanted, and the next question was what kind of carbon. I began to try various things, and finally I carbonized a strip of bamboo from a Japanese fan, and saw that I was on the right track. But we had a rare hunt finding the real thing. I sent a schoolmaster to Sumatra and another fellow up the Amazon, while William H. Moore, one of my associates, went to Japan and got what we wanted there. We made a contract with an old Jap to supply us with the proper fibre, and that man went to work and cross-fertilized bamboo until he got exactly the quality we required. One man went down to Havana, and the day he got there he was seized with yellow fever, and died in the afternoon. When I read the cable message to the boys, about a dozen of them jumped up and asked for his job. Those fellows were a bright lot of chaps, and sometimes it was hard to select the right ones."

One of the bamboo seekers, Mr. M'Gowan, who undertook to search the Amazon region, consented to be interviewed by the *New York Evening Sun*, which journal described his exploits in the following terms:—

"In pursuit of a substance that should meet the requirements of the Edison incandescent lamp, Mr. M'Gowan penetrated the wilderness of the Amazon, and for a year defied its fevers, beasts, reptiles, and deadly insects in his quest of a material so precious that jealous Nature has hidden it in her most secret fastnesses. . . .

"As a sample story of adventure, Mr. M'Gowan's narrative is a marvel fit to be classed with the historic journeyings of the greatest travellers. But it gains immensely in interest when we consider that it succeeded in its scientific purpose. The mysterious bamboo was discovered, and large quantities of it were procured and brought to the wizard's laboratory, there to suffer another wondrous change, and then to light up our pleasure haunts and homes with a gentle radiance."

Mr. M'Gowan's expedition met with thrilling adventures and hairbreadth escapes. For nearly six months he was without proper provisions, and relied upon good fortune for his bare subsistence. Perhaps the strangest part of his story, however, lies in the fact that after his triumphant return with his spoils he disappeared entirely, and his fate never transpired.

The search for the right bamboo cost nearly £20,000, and occupied a long time with weary delay and disappointment. Before all the searchers returned Edison had given up the idea of using bamboo fibre, and was experimenting upon quite

different lines with the object of producing an artificial carbon filament.

The world, which had been awaiting Edison's lamp with much excitement and a certain amount of scepticism, was enchanted with the ultimate production, and thousands of visitors travelled to Wenlo Park to see the public demonstration of the new light. But Edison was not yet satisfied, and was moving heaven and earth for the erection of a power station in New York from which current could be supplied to houses. The scheme, he knew, was practical, but it was all untried ground, and every detail had to be worked out by guess-work. After great difficulty he obtained a suitable building, but that was by no means all. The story of his struggles with his engines would fill a chapter by themselves, and I am afraid you must be content with hearing that in the end his trials were vanquished, and on the same day that his engines consented to run smoothly the first public electric-light service was inaugurated. The *New York Herald* claims to have been the first business house to install the new light, and the City Temple, London, was the first place of worship to make use of it.

These early years of Edison deserve all the attention we can give to them, since they tell of his marvellous powers of concentration and perseverance. It is true that he did not have to face thé material hardships common to most inventors, nor did he encounter the cruel discouragements which fall to the lot of many of the children of genius, but his most striking suc-

cesses have been achieved only by dogged determination in spite of repeated failures. He says himself that "Genius is 2 per cent inspiration and 98 per cent perspiration".

The invention of the phonograph was one possible only to the trained mind. It is generally attributed to Edison, but not quite accurately, for there were earlier investigators and experimenters. Edison was, however, the first to produce a practical machine, and it is interesting from the fact that the phenomena upon which it hangs were suggested to him by accident. During the time of his experiments in connection with automatic telegraphy, Edison tried various methods of vibrating a stylus. One of these was by means of an embossed strip of metal bearing the Morse signs in relief, and the operation caused the stylus to emit queer little sounds which attracted Edison's attention. It occurred to him that since certain waves or vibrations produced certain sounds, conversely certain sounds would produce certain waves, and that these might be registered in some permanent form. Edison described the growth of his idea in an article in the *North American Review* in the following words:—

"My own discovery that this could be done came to me almost accidentally while I was busy with experiments having a different object in view. I was engaged upon a machine intended to repeat Morse characters, which were recorded on paper by indentations that transferred their message to another cir-

cuit automatically when passed under a tracing-point connected with a circuit-closing apparatus. In manipulating this machine I found that when the cylinder carrying the indented paper was turned with great swiftness, it gave off a humming noise from the indentations—a musical rhythmic sound resembling that of human talk heard indistinctly. This led me to try fitting a diaphragm to the machine, which would receive the vibrations or sound-waves made by my voice when I talked to it, and register these vibrations upon an impressible material placed on the cylinder. The material selected for immediate use was paraffined paper, and the results obtained were excellent. The indentations on the cylinder, when rapidly revolved, caused a repetition of the original vibrations to reach the ear through a recorder, just as if the machine itself were speaking. I saw at once that the problem of registering human speech, so that it could be repeated by mechanical means as often as might be desired, was solved."

Probably the phonograph was the simplest of all Edison's inventions. In its pristine state it was nothing more than a cylinder revolved by turning a handle, over which the reproducing needle travelled, picking up the vibrations and giving them resonance. Since those days the clockwork motor has been added; and the gramophone, with its flat, disk-shaped records, outrivals the phonograph in popularity and portability, but the fundamental idea of each is the same. Improvements of necessity have been made in the

design, and material employed for records, needles, tone-arms, sound-boxes, and horns, but no modifications of details can modify scientific facts. If you scratch sound-waves upon an impressionable surface they are there to be re-embodied whenever you submit them to proper conditions; and it is this which makes the phonograph and its descendants one of the most fascinating of home amusements. It is also of great service in business houses. Few up-to-date offices are nowadays without a phonographic apparatus into which letters can be dictated, to be reproduced later on for the benefit of the typist. One wonders how long it will be before some ingenious soul invents a "scriptaphone" which will actually transcribe the spoken words?

How Edison's ingenuity laid the foundation of the moving-picture business is touched upon in the chapter on "Photographic Inventions". But even yet we have not exhausted the wonders produced by his genius; in fact it would be impossible even to mention them all here. It is a big jump from phonographs to electric trains, but no one incapable of big jumps need attempt to keep pace with Edison. And from electric traction on rails he turned his mind to electric traction on roads, and set to work to invent a storage battery which should enable electric vehicles to run without noise, smell, or vibration, cheaply, and for many hours without recharging. We have not yet had this battery, but that it will come eventually we need have little doubt. For the chances of Edison's

failure when once he has set his hand to a thing are shown by experience to be remote. Yet once or twice this shrewd American's inventions have failed to "pay" from the business point of view. There was the electro-magnetic iron-ore separator. In order to test this idea in the most practical manner Edison bought some land and built an entire village, which he named "Edison", whose inhabitants were employed in getting iron by the new process. But in spite of his enthusiasm and business ability Edison could not make the enterprise pay, so the works were closed and the comfortable little houses left desolate. Edison delivered a fitting epitaph when he said, in characteristic fashion: "Well, the money is all gone, but we had a jolly good time spending it!"

CHAPTER II

The Spread of Knowledge

Few of us ever stop to consider what an extraordinary thing language is. Not only do we need words to describe concrete things such as people, places, plants, animals, and the myriad objects we gather round us, but we talk about our actions, our sentiments, our hopes, fears, and physical feelings. There are over a hundred thousand words in the Anglo-Saxon language of to-day, and each of these words has some special significance. Yet of the thousand and a half million persons who occupy the world at the present moment only a fraction speak Anglo-Saxon—the others talk not in one tongue nor ten, but in a thousand different languages and dialects. There are four distinct languages spoken in the British Isles, while the number of dialects, many of them hardly intelligible to the inexperienced ear, compassed by British tongues is remarkable. Such a condition, however, becomes much more pronounced when we enter mountainous countries like Italy or the Balkan States. Even in little Wales the difference between north and south is so marked as to constitute distinct languages.

People who do not mingle much with their neighbours but live self-centred lives in isolated districts always tend to acquire a distinct mode of speech. At first it may be only a word here and there which changes, or some influential member of the community may introduce a particular intonation which becomes fashionable, and gradually the entire accent alters for better or worse. Then, unless these people are brought into contact with others speaking the same language, they will most probably evolve a new language of their own in the course of years.

The way in which words change is very well illustrated by the following little story. A friend of mine was appointed rector of a small parish in one of our northern counties. The village counted about two thousand souls, and was connected by railway with a large town several miles distant, so that it is not to be considered as an out-of-the-world place. Not long after the new rector had entered upon his residence he was visited by one of his humbler parishioners, who, after the customary greetings had been exchanged, blurted out: "I want a logiks."

"Oh, do you indeed?" said the rector. "I hope you'll get one, I'm sure."

The man looked disappointed, and it was only after a great deal of explanation that he was able to make the rector understand that what he really did want was an allotment garden. Now the rector was very much puzzled as to the origin of so peculiar a synonym for allotment. Ultimately he found out

that his predecessor had started the allotment system in that neighbourhood, and had taken his visitors to see the plan in operation with the words: "Come and see the animals working in the zoological gardens." The rest was easy to understand, for "logiks" clearly was nothing but a corruption of "zoological".

Except for instances such as this, the language of civilized races has stood still for the last two or three centuries. Many new words have been introduced, but the old ones have kept their form. Earlier in history, however, they were constantly changing. Take any good etymological dictionary and look up some of the oldest words you can think of—the oldest words, of course, being those which describe some fundamental part of daily life. A few Ancient British words remain in use in English. The period of Roman occupation is represented now by only four words, one of which, "street" from "strata", we may mention. The Danes left us a few words, but the foundation of our modern speech was laid in Anglo-Saxon times. Here are a few words which have come to us through Anglo-Saxon: bread, elbow, white, go, man—all words which are essential. The spread of Christianity and the consequent visits of Italian monks to these islands may have introduced new words, as they certainly introduced new manners and customs; but Latin being the official language of the whole of Western Europe at that time—with the exception of such parts as were still savage—it is

easy to understand how so many Latin words became parts of our tongue. The Norman Conquest wrought many radical changes in English life, and the nature of those changes may be traced with the help of the dictionary. You remember, of course, the passage in *Ivanhoe*:—

"'Why, how call you those grunting brutes running about on their four legs?' demanded Wamba.

"'Swine, fool, swine,' said the herd; 'every fool knows that.'

"'And swine is good Saxon,' said the Jester. 'But how call you the sow when she is flayed, and drawn, and quartered, and hung up by the heels like a traitor?'

"'Pork,' answered the swineherd.

"'I am very glad that every fool knows that too,' said Wamba; 'and pork, I think, is good Norman-French. And so, when the brute lives, and is in the charge of a Saxon slave, she goes by her Saxon name; but becomes a Norman, and is called pork, when she is carried to the Castle-hall to feast among the nobles. What dost thou think of this, friend Gurth, ha?'

"'It is but too true doctrine, friend Wamba, however it got into thy fool's pate.'

"'Nay, I can tell you more,' said Wamba in the same tone. 'There is old Alderman Ox continues to hold his Saxon epithet while he is under the charge of serfs and bondsmen such as thou, but becomes Beef, a fiery French gallant, when he arrives before the


Photo Topical

THOMAS EDISON IN HIS LABORATORY

Chap I

worshipful jaws that are destined to consume him. Mynheer Calf, too, becomes Monsieur de Veau in the like manner; he is Saxon when he requires tendance, and takes a Norman name when he becomes matter of enjoyment.'"

That describes one effect of the Norman Conquest to perfection. The Normans, fiery warriors though they were, were dapper, dandy gentlemen compared with the recently conquered English. We have to thank them for countless words relating to the niceties of life, to arts, crafts, sports, and sciences—in fact to everything, and it was much, in which their civilization surpassed that of the English. From Italian pilgrims and professors we learnt more, while the Crusaders brought back Eastern words and expressions. So our language grew, every war and every foreign trading venture adding to its grace and richness. But we can never get to the beginning of it. We may trace a word to its Anglo-Saxon source, then to a Teutonic or Latin root, possibly afterwards to a Greek one. From Greek the chase becomes difficult. We may follow our quarry through Phœnicia to Egypt, but there I think we shall be obliged to bring up.

However far back we may go, we can never find the beginning, for we can by no possible means find a word older than the oldest alphabet. Until men began to write they could not perpetuate for us the words they used, and we must take it for granted that human beings inhabited the earth for a very long

period before they began to write. But they had, nevertheless, their own methods of communicating with one another without the aid of speech, for such a practice became necessary very early in the history of man. It is quite clear that even the most primitive savage requires a code of signs for three distinct emergencies—to remind himself of something that has been done or that has to be done, to mark his own property, and to convey a message. Amongst the Indians of North America a system obtained of stringing beads of different colours on to belts of wampum. White beads signified peace; purple, war; and so on. The natives of Australia send messages by means of a stick on which notches are cut. The sender of the message cuts the notches with a mussel shell, saying the message as he does so, by which means the carrier of the message associates a special word or point with each notch, and is able to recite it fluently when he arrives at his destination. The Incas of Peru made use of an instrument called a "quipu" when they wished to communicate with one another. On to a thick rope thinner ropes of varying colours were knotted, these again being knotted together in certain patterns. A similar device was employed in Europe. It is said that during the expedition of Darius against the Scythians he once left a small body of Greeks to protect a bridge over the River Ister. To the captain he gave a thong in which was a number of knots. One of these knots was to be undone every day, and if Darius had not returned on the day that the last

knot was untied, the bridge was to be broken down and the men were to retire.

In Scandinavia a system of divination called *kefli* used to be practised by means of slips of beechwood on which were scratched marks signifying certain persons, and the same system survives in remote districts of Scotland to-day under the name of *kaivel*. After a day's fishing the partners in a boat divide the catch into heaps, one heap for each man and one for the boat. Then each man marks a stone with his own particular sign, and the stones are given to some person having no interest in the boat, who throws the stones one by one on to the separate heaps.

Devices such as the notched stick and the quipu, however, were employed only by men who had no knowledge of writing. Picture-writing, or to give it its professional name, ideographic writing, is, if not as old as the hills, certainly very, very old. Ideograms were pictures or signs representing things or events. No fewer than six distinct forms of ideograms are known to archæologists—the Cuneiform, the Cretan, the Hittite, the Chinese, the Egyptian, and the Mexican. These forms developed into phonograms or representations of sounds and syllables, and some developed still further into genuine alphabets. The advantages of alphabets over picture-writing are obvious. The Egyptian system of picture-writing comprised four hundred phonograms, whereas the alphabet which the Phœnicians based upon it contains only twenty-two consonants. The letters which

the Phœnicians used bear a strong resemblance to the Egyptian, easily traceable when we remember that the Egyptian characters were written upon papyrus with some kind of pen, whereas the Phœnicians desired an alphabet capable of being cut in stone, and on this account they invariably substituted straight lines for curves. The Greeks derived an alphabet from the Phœnician during the tenth century B.C., and at that period it was fashionable to write from right to left, instead of left to right as we do now. A little later on, the still more inconvenient form of *boustrophedon*, or "ploughwise" writing, was introduced, that is to say, the scribe wrote backwards and forwards as a plough goes up and down the furrows; but by the end of 700 B.C. the left to right system was well established.

From Greece Italy derived her alphabet, and the Roman Empire and the Roman Church spread these Latin characters over the whole of Western Europe, America, and Australia. The introduction of writing into this country was probably achieved by the Church rather than the Empire. Latin characters, however, were not unrivalled in Britain, for two other forms of writing, known respectively as the Ogmic and the Runic, were widely in use. The Ogam alphabet is very simple, each letter being represented by one or more straight or diagonal strokes above or below a central line. This line was strictly the edge of the block of stone, and the reader began at the bottom and read upwards; but the inscriber did not always

understand what he was writing about, so that in some cases the sentence is upside-down, and sometimes the scores are made in the middle of the block instead of at the edge.

The Ogam alphabet was invented in Ireland—it is believed by an enterprising native who had seen some Roman engraving an epitaph on a tombstone. Nearly all the Ogam remains in the British Isles, and there are close upon three hundred, are epitaphs. Most of them are in Ireland, but there is one in Cornwall, a few in Devonshire, a small number in Pembrokeshire, one in Denbighshire, and about fourteen in Scotland, scattered in the counties of Fife, Elgin, Aberdeen, and Sutherland, and the Shetland and Orkney islands. To the Ogam stones of Pembrokeshire and Devon great importance is attached, from the fact that the inscriptions are written in both Ogmic and Latin characters, and this circumstance has been of great value to archæologists. The Ogmic alphabet was never really forgotten, but it had received little attention before the finding of these bilingual inscriptions.

Ogmic writing, however, was practised only by a few accomplished members of a small race. The other ancient alphabet which was used in the British Isles—the Runic—may be traced across Europe to its birthplace upon the shores of the Black Sea. Its form was based upon that of an old Greek alphabet, and its date can be established approximately from the fact that its direction was retrograde, that is to say, written from right to left. Goths, Visigoths, and

Burgundians spread this alphabet across Southern Europe to France and Spain, and across Northern Europe to Scandinavia, whence it was brought to the shores of Britain. No traces of it are found in Germany. Runes, or rune-staves as the letters should be called, were cut on slabs of wood; and this circumstance accounts for certain modifications of form, since horizontal strokes which would follow the grain of the wood had to be avoided. Rune-staves, therefore, are made entirely of perpendicular and diagonal lines.

At a time when only the very learned could write, and learning was regarded with awe, the faculty of writing carried with it mysterious and magical powers. The very word *run*, in Old Norse, meant "secret", something not to be told or understood. What wonder, then, that the ignorant attributed a significance to the rune-staves and used them as charms and spells against evil of all kinds? Numberless are the legends which have arisen around the rune.

After the introduction of Christianity and the establishment of monasteries, the study of writing was begun seriously. Copies of the Scriptures were rare, and every monastery wished to possess one. Monks all over the kingdom were soon hard at work copying out portions of the Bible. Nowadays we write a book in a few months, and frequently so badly that we have to type-write it before the printer can read it. But in mediæval Europe the copying of a book was a labour of love to which men gladly devoted their whole lives and energies. Most beautiful are some

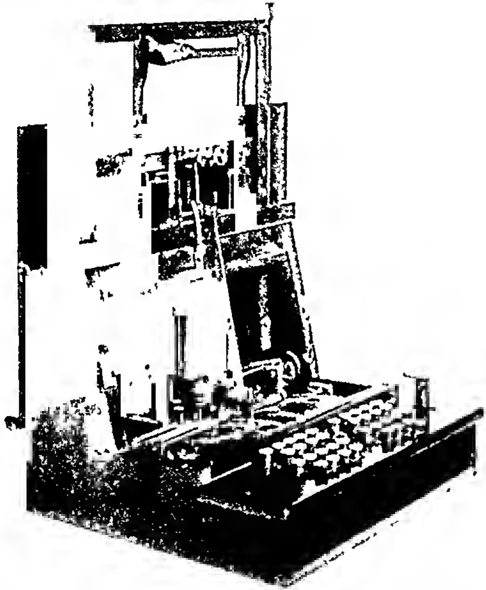
of the illuminated manuscripts which have been preserved for us in museums. Years of patient toil were expended in the production of these scripts, and to them we owe the Bible which is so beloved a book to-day.

At a time when the centres of learning were isolated, and but little communication existed between foreign countries, it is easy to understand that there was no standardized form of writing. The letters all followed approximately the same lines, but differences crept in. Each pupil copied his master more or less faithfully, but perforce introduced characteristics of his own which, in due course, he passed on to another set of pupils. In this way national writings became established, and in mediæval Europe several scripts, almost or wholly illegible to those who did not use them, were in vogue. Material also had a great influence upon the writing: for instance, writing on parchment is always of a particular kind, the letters being upright, formed separately, and rather elaborate, whereas the use of paper tended to make the writing careless and irregular.

The study of Palæography, or the science of ancient writing, is one of absorbing interest, and will take you far back along the ages. Handwriting to-day is a lost art, but it is none the less interesting on that account. Modern books are printed in "Roman type" which is directly descended from a script described as the "Irish semi-uncial". The Irish semi-uncial also came from somewhere else originally,

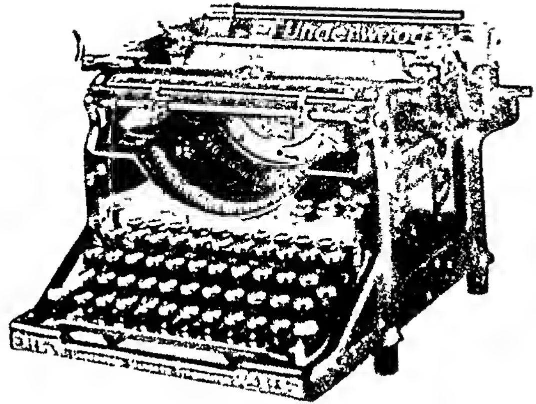
probably from Southern Gaul, but that point has never been established. This script is deservedly the most famous of all mediæval scripts, and produced the wondrous Book of Kells, which, made some time in the seventh century, still remains for us to see in all its glory in the museum at Dublin. Irish missionaries carried their school of writing to Northumbria, as two books remain to testify—St. Chad's Gospels, which may be seen at Lichfield, and St. Cuthbert's Gospels, now amongst the treasures of the British Museum. The Northumbrian uncial was the parent of the Caroline minuscule. The Emperor Charlemagne invited Alcuin of York to teach writing in his school at Tours, and his particular form of script was soon, on account of its beauty and legibility, spread all over Europe under the name of Caroline minuscule. This script, which flourished in the eleventh century, and was perhaps the most beautiful writing ever used, gave us the form in which this type is made. The black letter, or Gothic, was a degenerate style of Caroline minuscule in which the first books were printed, but its vogue did not last long in any country except Germany, where it is still in use.

It is interesting, though no doubt a waste of time, to speculate upon the state of the world to-day supposing the printing-press had never been invented. How far should we have progressed if every book still had to be written out by hand? I think we must answer, not very far. I think we must take it for granted that few people would have been able to buy



PRATT'S ORIGINAL TYPEWRITER

The leading details of this machine were patented in 1864. The paper was carried in the vertical frame



MODERN TYPEWRITER

The machine illustrated is the result of successive improvements by many inventors.

the books, and fewer still would have had the patience, or even the ability to read them. There are many people still to be found who can neither read nor write, although they have been to school, and although every blank wall, every gate, every tram-car or omnibus or railway carriage bears some message to them in "Roman type". Yet how many more illiterates there would be if there were no cheap books, no familiar posters, no circulars, tickets, notices of a million kinds in "Roman type"? It is the supply of cheap literature which has encouraged people to learn to read. If for any reason that supply should cease, it is probable that in a generation or two the proportion of illiterates in the community would have risen enormously.

To what circumstances, however, do we owe our cheap books, and the consequent spread of knowledge amongst the people? Well, that is a question which cannot be answered in two words. The printing-press alone is not responsible, since printed books were very dear, even so late as the beginning of the nineteenth century. Nobody could print books to be sold at a low price when paper, ink, type, and all other requisites were scarce and expensive. The revolution which has taken place in every branch of commerce during the last hundred years has resulted in the cheapening of nearly all commodities—some few have risen in price—and consequently nearly all manufactured articles are produced with very much less expense. We must also take into consideration the

increased demand for books created by the advance in education, which itself was made possible by the printer, improved conditions of travel and intercommunication, and the keen competition in every profession and business which makes highly specialized knowledge indispensable. We have only to read the lives of some men who have risen to eminence from humble beginnings to realize the difficulty with which they obtained their first books. "He had no money to buy books" is a phrase with which we meet when reading the biographies of many famous men. Nowadays few people suffer from such a disadvantage. However poor a man may be, if he be really determined to learn, he will be able to save sixpence to buy a new book, which he may, in fact, be able to buy for less at a second-hand shop, or to read for nothing at all in a free library. But it is open to question whether the new order of things will produce the patient, laborious scholars who alone could win success when neither cheap education nor cheap books were to be had.

Unfortunately, the actual invention of printing is a mystery. It is most likely that the Chinese were the first people to practise this craft, but the date of its introduction into Europe is a matter round which has raged the bitterest discussion. No controversy, of a non-religious nature, has lasted so long or been waged with such violence as this one concerning the invention, in Europe, of printing. Two countries, Germany and Holland, both claim the distinction; Germany

putting forward Gutenberg for the honour, and Holland one named Coster. It is quite impossible to formulate here the arguments set up by each party, or to try to decide between the claimants, and the matter is really of no importance. Rather let us leave the subject severely alone, merely recognizing the facts that early in the fifteenth century printing was carried on at Haarlem by Coster and at Mainz by Gutenberg; that Mainz was sacked in 1462 and the printers scattered all over Europe, taking with them their knowledge and abilities. In this way the craft spread rapidly.

William Caxton, the man who introduced printing into England, had studied the trade in Cologne, and later possibly under Colard Mansion, a printer of Bruges, in which city he lived for many years. He returned to England in 1471, and it was in 1476 that he set up his first printing-press at the sign of the Red Pale in Westminster. While in Bruges he had printed the first English book, the *Recuyell of the Historyes of Troy*; but the first book to be printed in England was the *Dictes and Sayings of the Philosophers*, which he published in 1477. From this date until his death in 1491 Caxton employed his life in the greatest industry, translating, editing, and printing books of all kinds. Few of them are to be found to-day in their entirety, but even fragments of his work have a high value. *The Game and Playe of the Chesse*, one of his earliest productions, was sold in 1885 for £1950.

We know very little about the printing-press by which Caxton produced his books. No picture or description of it remains, but we can imagine it as being a very clumsy, heavy contrivance, necessitating great exertions on the part of the operator. The type, of course, was of wood. Probably the press was similar in construction to one known to have been in use in the earlier half of the sixteenth century. This consisted of an upright frame, down the centre of which ran a screw, provided with a movable handle, terminating in the "platen". When the handle was screwed down, the platen was made to press heavily upon the pages placed between it and the solid bed of wood or stone on which the type rested. The impression being made, the handle had to be screwed up again to release the printed copy and to allow of another page to be put in place. In the next century several important improvements in this kind of press were made by Willem Janssen Blaeu, of Amsterdam, who, by means of a block and cords, facilitated the operation of screwing down the platen, and introduced an iron lever much easier to manage than the old wooden handle. He also devised a means by which the solid bed was moved backwards and forwards with greater ease.

The first iron printing-press, in every way a great advance upon the wooden presses, was constructed at the beginning of the nineteenth century according to the designs of the Earl of Stanhope. The Stanhope press is still used, though not so largely as is the

Albion press, built a little later. Wherever exceptionally fine work is required, hand presses are used. The Kelmscott Press, inaugurated and maintained for a short time by William Morris, employed Albion presses, and produced some wonderful specimens of beautiful printing.

In printing, as in so many of the other industries considered in this book, the eighteenth century drew to its close in an atmosphere of impatience. "Less labour and greater speed" was the cry of the master printers. In 1772 the predecessor of the great rotary machines of to-day was patented, and its inventors claimed for it that by its use printing upon paper and woven fabrics "would be greatly facilitated, and rendered much less expensive, and more perfect and exact". Following upon this came, in 1790, the suggestion of William Nicholson, an author and editor, for a machine in which the forms were to be fastened to a cylinder. Nicholson never built a machine, so we cannot regard him as an inventor, but he undoubtedly provided ideas for practical men to work upon.

One of such men, and the one to whom we probably owe most, was Friedrich König. After many disappointments he persuaded a London printer named Thomas Bensley to take up his case, and with this help he was able to patent, in 1811, a cylinder press. For the next few years he worked at this machine, improving it in many ways, and in 1814 he had the satisfaction of receiving orders from the *Times*. The machine he built for the *Times* began work on

November 28th, 1814, so the *Times* of that date is the first newspaper ever printed by steam. Only one side of the sheet could be printed at a time, and it took an hour to complete nine hundred sheets. At the time this was considered lightning speed, but we should call it impossibly slow nowadays. It was not until 1818 that König perfected a method by which both sides of the sheet could be printed at once. This was achieved by means of two cylinders. During its passage from one cylinder to another the paper was turned over by tapes, so that the form of the second cylinder printed the blank side of the sheet.

The printing machine of to-day is a thing so marvellous that, were Caxton to see it, he would probably declare it to be an invention of the evil one. In a modern printing works, everything is done by machine. When we think of the extraordinary efforts made by the earliest printers to produce one printed page, our modern machines which can print something over a hundred thousand twelve-page newspapers in an hour seem little short of miraculous. But these mechanical giants of the newspaper offices are direct descendants of the hand presses of Caxton and Blaeu. The introduction of steam or electricity as motive power lessened manual labour and accelerated the production, but it did not alter the principle of working in any degree.

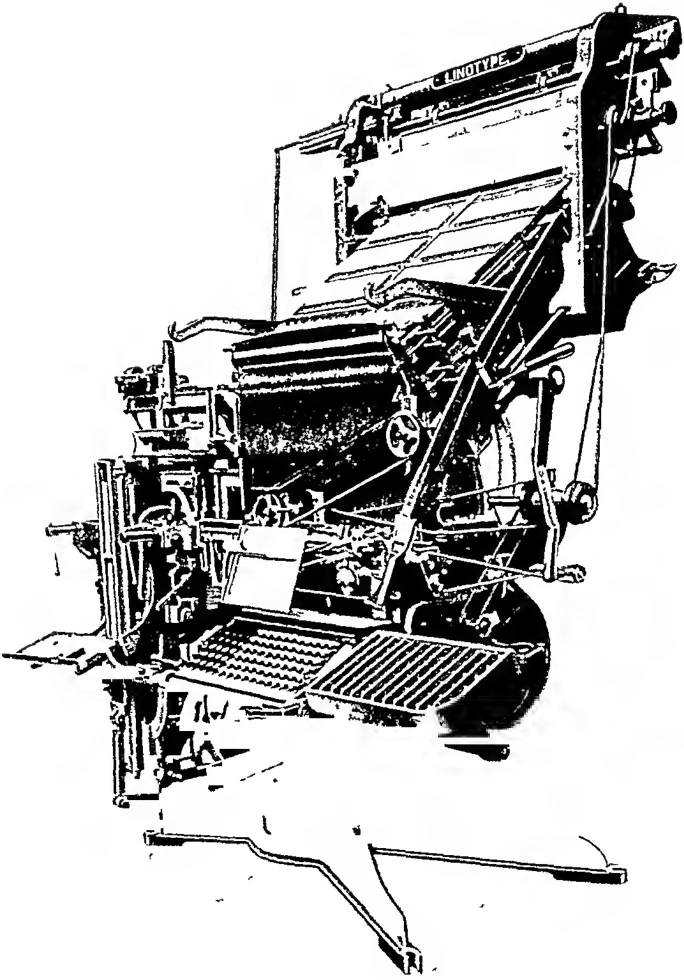
Printing machines are of two chief kinds: reciprocating and rotary. Reciprocating machines convey the impression by means of a flat bed which travels

backwards and forwards, while in the case of rotary machines the impression is taken from a cylinder round which the paper passes. Machines known as type-revolving machines follow very closely the designs of William Nicholson afore-mentioned.

Caxton cut all his type out of wood by means of sharp tools—that is, if he cut them at all; but many authorities allege that he always used type of Dutch manufacture. Certainly all his type is of the Dutch and Flemish style. The first English type-foundry worthy of mention was that of John Day, and that only flourished between the years 1546 to 1584. The names of Caslon, Baskerville, Jackson, and Vincent Figgins are all famous on account of the beautiful type their owners produced during the seventeenth and eighteenth centuries. But no British type could compare with the best French until the days of Alexander Wilson, a Scotsman, and his sons. With the passage of years this style came to be regarded as too ornate, and the plainer shape of letter such as is used at the present time acquired its popularity. About the middle of the last century William Pickering revived Caslon's type with great success, and this is the type used in many of the best books printed since that time.

For the purposes of newspaper-printing works, however—and we shall not have room to consider any others in detail—the clearest and plainest type has to be used. In small works the composing is done by hand—the "comp" being a skilled individual

who can pick the required letters, stops, and spaces out of his case and fit them into his "stick" at lightning speed. But rapidly though he works, he is not rapid enough for modern requirements. His place in large works is taken by type-setting machines. The Mergenthaler, or Linotype, is a machine largely used in newspaper offices on account of its convenience and the rapidity with which it can be worked. The operator sits in front of a keyboard somewhat similar to that of a typewriter. Pressing upon the keys, he brings into position a matrix or mould of the required letter. When the line is completed the operator spaces the words by means of a device called the justifier. The spacing of the lines was one of the most obstinate problems in connection with the Linotype, and for a long time it defied all attempts at solution. Mergenthaler achieved it at last, however, and Linotype machines can be worked now by one operator. The line of matrices is then carried along until it comes to a wheel. One touch on the wheel causes exactly the proper amount of molten metal to fall into the matrices, and in this way a solid line of type is cast. The matrices have now done their work, and may return to their cases. The mechanism which performs this action is very interesting and wonderful. The matrices are automatically transferred to a distributing bar, on to which they grip by means of teeth cut both on the matrix and on the bar. They are forced to move along the bar, and in due course each matrix comes to some particular spot where its teeth



LINOTYPE MACHINE

The machine, which is worked by a single operator, makes and sets lines of type solidly and not in separate letters. Its use has quickened, simplified, and cheapened newspaper setting.

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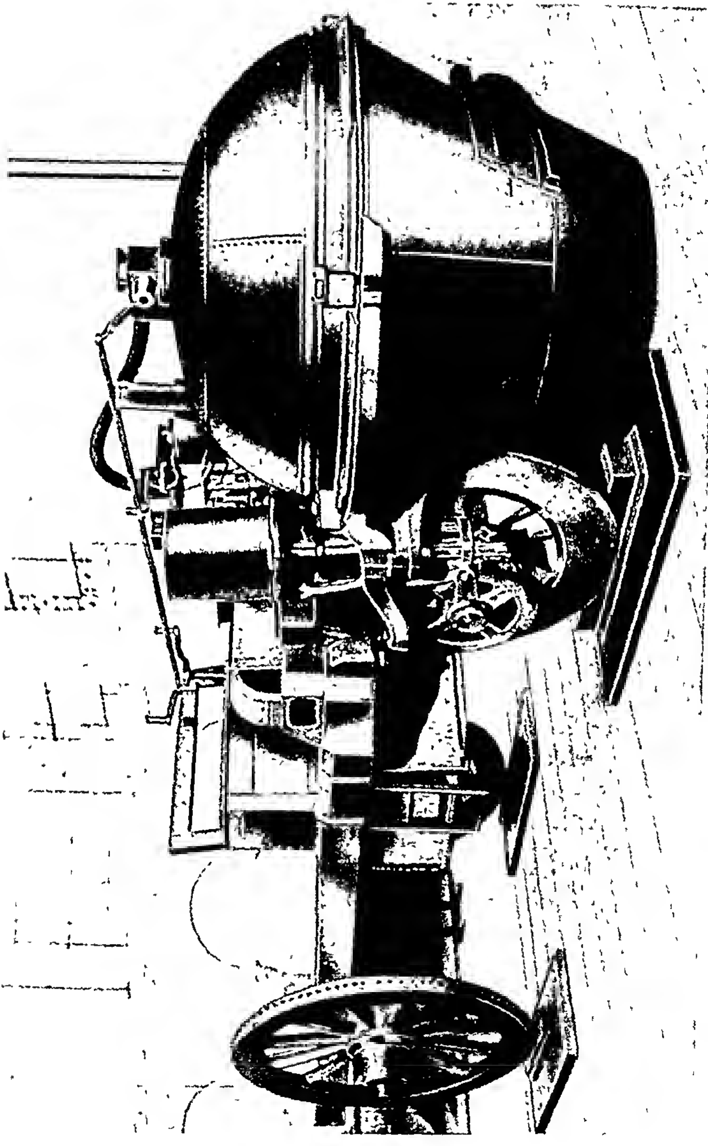

cannot grip, owing to a change in the teeth on the bar. Then it falls from the bar into a groove which carries it straight into its own box. The enormous advantage of one of these machines over the compositor is shown by a comparison of the work done by the two methods. Whereas the Linotype can set twelve thousand types in an hour, the compositor's average speed is five hundred an hour.

The production of a daily newspaper, indeed, may be said to call more upon man's inventive faculty than almost any other article in daily use. We start with the reporter, writing in shorthand with a fountain pen, telegraphing or telephoning his notes to the newspaper office, while from all quarters of the globe news is arriving by wireless telegraphy or the submarine cable through the medium of the uncanny tape-machine. Simultaneously steam saws are at work cutting down forests, giant machines are grinding and pounding the trunks to pulp, and other machines are rolling the pulp into paper. The paper is brought thousands of miles by steamboat and locomotive, being handled by mammoth electric cranes on the way, and finally reaches the machine which holds a five-mile roll in its place as easily as a child holds a ball. Somewhere else are factories making ink specially adapted for newspaper printing—and the actual inking of the type face was a stiff problem before the right man thought of the right way—and we must not forget the titanic forges which are always making machines for making other machines. We

have gone a long, long way from our first compound manufacture, have we not?

There is still another instrument to be considered under this chapter heading—the typewriter. It may not at first appear that the typewriter has had any effect upon the spread of knowledge, but a few moments' reflection will convince us that this is so. The work of all business houses has been simplified to an extraordinary degree by the typewriter, and we may take it as an axiom that wherever labour is simplified production is increased. Increase of production, increase of trade, increase of profit, increase of leisure—there you have the whole cycle of circumstances tending towards better conditions of the community, and consequently to a higher standard of thought. The work of four toil-worn quill-drivers is now done by one deft-fingered girl with a machine, and the intolerable cramp common to those who write much is a thing of the past. But the typewriter was not admitted to the commercial world without a struggle, in fact there are few successful inventions which have had so long a period of probation.

To find the first record of any such machine we must go back a long way to the early years of the eighteenth century. But although a patent was issued for what we may take to be the first attempt at a mechanical writer no trace of a model remains, and presumably the inventor died without bringing his design to any practical use. A machine was actually made rather more than a hundred years later by an

American named Burt. Unfortunately both design and machine happened to be in the Washington Patent Office when the building was burned, and thus another effort was rendered valueless. Meanwhile the idea had travelled across the Atlantic, and a citizen of Marseilles patented a writing machine in 1833. In the 'fifties further progress was made by Britain, when Sir Alexander Bain and Sir Charles Wheatstone perfected their machines for recording telegraphic messages. But still greater credit may be given to Britain in the development of the typewriter for the work of Littledale and Hughes. These gentlemen did much towards improving existing ideas as to mechanical writers, not in the interest of commerce but in the interest of the blind. Their machines were designed to enable the blind to write, and back across the Atlantic flowed the inventive current to animate the soul of a New Yorker to the same end, and across the Channel to France.

The missing link between these and other early efforts and the commercial typewriter of to-day may be found in the machine invented by John Pratt. Pratt called his machine a "pterotype", and his letters, in capital type only, were arranged upon a wheel. There was no space key, but spacing was obtained by pressing any key insufficiently to produce a mark. Fortunately a description of this machine fell into the hands of three men who were already keenly alive to the possibilities of such an invention. These were three amateur mechanics of Milwaukee,

named Latham Sholes, Samuel Soule, and Carlos Glidden. Taking Pratt's machine as a model these three evolved a pattern of their own, and then amused themselves by typing letters to their friends. In this way they attracted the notice of a wealthy business man named Densmore, who proposed to buy the idea and start it commercially. When he ultimately saw the machine, however, he suggested such radical alterations in its economy that Glidden and Soule washed their hands of the whole thing, and left Sholes and Densmore to tackle the problem in their own way. Densmore's way was to aim at perfection, and Sholes's way was to do what Densmore told him, so that one after another machines were built and rejected as being unfit for general commercial use.

At last Densmore was satisfied, and considered that a point approaching perfection had been reached. But he mistrusted his own ability to graft his scion upon the gnarled old tree of American commerce, so he enlisted the services of a friend blessed with the gift of the gab. This friend bore the name of Yost, now associated so closely with the typewriter, and together they called upon the firm of Remington & Sons, at that time occupied with the manufacture of small firearms. Thus upon a foundation of doubt and incredulity have been built two at least of the great typewriter factories of the world. For Remington at first would have none of the typewriter, and only consented to undertake its manufacture after prolonged onslaughts on the part of Yost.

From that time forward the history of the typewriter loses itself in the subtler question of the psychology of salesmanship. Admittedly a practical and undoubted factor in office efficiency, and of immense use to professional and business men of all kinds, it yet did not "go". Many and various were the agencies and selling combines attempted, but all were ineffectual. Yost, ultimately finding himself debarred from participating in the "Remington", invented a machine of his own. After years of struggle and scarce-averted disaster, the typewriter was taken up by Wyckoff, Seamans, & Benedict, who eventually succeeded in persuading the commercial world that the machines had come to stay.

CHAPTER III

Travel

Supposing some friend of yours were to say to you: "Look here, you deserve a holiday. Where would you like to go?" what would you answer? Knowing that you might go anywhere; that time, distance, and expense need not be considered at all, what country out of the whole world would you choose to visit, and by what route would you travel? A hard question! Would you go eastwards to see the pagodas and gardens of China, the temples of India, the sacred places of Tibet and Arabia? Would you go south to the pine-clad heights of Cape Town, the thunderous falls of Nyanza, or the calm beauties of Sydney Harbour? Or would you go westwards across the endless, rolling prairies to the great mountain ranges which guard the Pacific, thence perhaps to Japan, the land of islands and blue sea, of perfect mountain and perfect flowers? Or would you go to the far North, to the crags and bergs of Arctic lands lighted by the Midnight Sun and the Northern Light? Or would you go—but it is impossible to enumerate all the enchanting places to which you might go. The whole world calls to you, beckoning with mystic

fingers, speaking of delights which you may know if you will but go to look for them.

Foreign travel is no longer the monopoly of the very rich or the very adventurous. The humblest little clerk, who trembles with excitement at the thought of a ride in a motor char-à-banc, may, by careful hoarding of his spare pence, take a holiday on the Continent. The weariest little governess, whose working days are spent in a gaunt building full of clamorous children, may for a few brief days feast her eyes upon the majestic snow-clad Alps, and soothe her senses with the music of their waterfalls, at the cost of a few pounds. Then, if they never manage to repeat their puny extravagance, they still will have something to remember, something to talk of and think of, quite beyond their ordinary experience. "During my holiday in Brittany" and "When I was in Switzerland" will preface myriads of happy reminiscences.

But—you knew I was coming to a "but", didn't you?—but such a right and proper state of things is of recent growth.

To the Phœnicians belongs the honour of being the first nation systematically to practise overseas travel, although before their time trading expeditions had been sent out by the Egyptians, and of course the overland caravan was already old. In all their works the Phœnicians were impelled by the commercial instinct. They were not missionaries and they were not warriors—indeed their history is a remarkably

peaceful one—but they were the keenest of traders. They traded in almost everything, with savages in Africa and with polished gentlemen of Egypt and Babylonia. Their own original products were few, the world-famous purple dye being their one genuine invention, but they were clever enough to imitate and improve upon the manufactures of other nations. For instance, they not only copied the glass-making of the Egyptians, but by using a particular kind of sand found at Tyre they were able to make a finer kind of glass than their teachers. Their own country also provided them with an abundance of natural wares, dates, timber, and so forth, which they shipped to all parts of the world as they knew it. Everyone knows of their intercourse with Britain, when they exchanged for the precious tin and copper of Cornwall their trinkets and ornaments, their cloth and glass vessels. It is only reasonable to suppose, for instance, that they taught the Britons their own words for tin and copper, and learnt in return the British for meat and drink or other essentials. Beyond this, they established in every place they visited, a certain standard of commercial honesty. I am not going to say that they never drove a hard bargain; in all probability they were very keen in the furtherance of their own interests, and they are known to have played the part of pirates from time to time; but their strict rule was one of fair dealing. They also introduced their system of weights and measures into every country they found unsupplied with such a convenience. It is

SCIENTIFIC OBSERVATION IN THE ANTARCTIC

Dr Wilson and Lieut Bowers reading a thermometer on Ross Island during Capt Scott's Antarctic Expedition The photograph was taken by flash light by Herbert G Ponting during the three months' Polar night, when the temperature was 52° below zero *Chap III*

well worth noting that of the great maritime cities of Phœnicia, Byblos, Berytos, Sidon, Tyre, Sarepta, and the others, not one has disappeared altogether, although all date from about 1500 B.C., and no new ones have arisen on that coast.

Another great people, the Venetian, which thrived exceedingly and helped to advance the world simply by commerce, began its existence on the shores of the Mediterranean in a very humble way at a much later period.

These people, whose life was passed upon the sea, soon acquired a renown for seamanship. Their boats, built upon a plan learnt from the Jadarans, the best shipbuilders of the Adriatic, carried salt to all the ports, and soon commanded a profitable carrying trade in merchandise of all kinds. In 584 they acquired a footing in the East by claiming the right to trade in Constantinople without paying the heavy charges to which foreign traders were liable. In this way they were able to buy the products of Asia, the precious silks, spices, woods, and luxuries of all kinds, and sell them again at a lower price, and with greater profit to themselves, than their rivals. Century after century saw the Venetians becoming richer and more powerful, and obtaining dominion over ever-extending territory, until at the time of the Crusades they were a people upon whose will much depended.

The Crusades brought about much intercommunication between different races, and had beneficial and wide-spreading results. Fundamentally they were

religious campaigns, but there can be no doubt that love of battle induced numbers of men to join who would never have heard the call of religion. It only remained for Venice to introduce the commercial spirit to find our three factors of progress. At the beginning Venice disapproved of the Crusades. War, she said, interferes with commerce. We will have nothing to do with it. But, when the apparently endless procession of men carried in boats from Genoa and Pisa began to pass down the Mediterranean, Venice modified her views. The wars, she thought, might after all be made profitable, properly handled. Thereupon she made ready great fleets of transports, which she placed at the disposal of the Crusaders, demanding in return not only a heavy fare from each passenger, but a share in all profits made by the company. With every one of her transports her great mercantile firms sent their representatives, who whiled away many a tedious hour of the voyage for the soldiers of every rank by their lively talk and exhibitions of their wares. We may be sure that good business resulted from these expedients.

Commerce was the dominating influence which brought about the expeditions around Africa and to America. The wealth of the East dazzled men's imaginations; her mystery and remoteness appealed to the adventurous; and the fortune to be made by obtaining cargoes of her precious goods, unburdened by the dues demanded by Saracen and Turk, attracted th [illegible] The northern seas next

came under the notice of mariners. John Cabot, who was the first man to sail from England to the continent of America—the first European, indeed, since Bjarni, at least who returned to tell the tale—mentioned the abundance of fish in the seas off Newfoundland. This circumstance was noticed and repeated by one man to another, until at last a fishing-boat ventured there. The Portuguese led the way in this case, but the British fishermen were not slow to follow them. Naturally such a voyage called for the virtues of courage and endurance in the highest degree. The men had to face one of the stormiest and most dangerous parts of the ocean, a region of fogs, gales, and icebergs, in boats that would be condemned to-day as unsafe for sailing on a tranquil lake. War between one or other of the maritime nations of the time was a matter of habit, and apart from recognized enemies there was always danger from pirates, while even among the crews deeds of violence and passion were not infrequent. Such a condition of things resulted inevitably in producing a race afraid of nothing and equal to anything. These Banks fishermen became renowned for their daring and resourcefulness, and furnished crews for many of the bold roving expeditions which set out to harry the ships of Spain.

The Banks fisheries being well established, and the Northern Atlantic having lost its terrors, seamen next ventured to explore it farther with a view to finding a northern trade-route to China. In this connection

the name of Henry Hudson deserves lasting commemoration. He did not discover the North-West passage, but he made known to Europe the enormous possibilities of fur-trading with the Indians on New York bay, and he also found the great gulf to which he gave his name. How much more he might have done we cannot say, but he came to an untimely end, his men turning him adrift in an open boat. Baffin, who sailed as far as Baffin's Bay, satisfied himself and the world at large that a north-west passage was not practicable; but in the meantime a north-east passage to Russia had been found by Chancellor, acting under instructions from the Merchant Adventurers' Company. By this means very valuable trade relationships accrued to the British, which afterwards provided large funds for other expeditions.

Unfortunately furs, fish, spices, and stuffs were not the only commodities in which early traders dealt, nor did they always carry out their negotiations with strict equity. The southern continents especially were the scenes of violent and outrageous acts, and witnessed the burning and plundering of towns and all the horrors of the slave trade. This dreadful trade, as practised in the later Middle Ages and in modern times, had not the thinnest cloak of religion to shield itself. Nevertheless we cannot overlook the fact that it led to intercourse between nations, a thing which has in it always something of good. It is possible that the exploration of Africa, a task so arduous and perilous that it has been undertaken only by men

actuated by the strongest of motives, might not have advanced nearly so far as it has, had it not offered to traders its inexhaustible supplies of "black ivory". Even in this enlightened age no one can read authentic accounts of the rubber and cocoa industries in Africa without revulsion. But these operations of commerce are so profitable that all the dangers of climate and disease, of unmapped lands and fickle water supply which Central Africa presents, are gladly encountered by men anxious to make money. But there is another class of men which has done as much for Africa as the traders: the devoted heroes of science and religion, Baker, Livingstone, Stanley, and others, who in pursuit of their object have not hesitated to risk or give up their lives.

In the Middle Ages the Church was a harsh mistress to those who did not obey her slightest behest, but her very exactions led to results most beneficial to the world at large. So long as the Christian faith has reigned men have been willing to die for it; and more than that, they have been willing to die or to give up all their worldly goods in support of their own personal convictions with regard to the outward expression of the faith. Consequently, when the all-powerful Church threatened heretics with banishment, she was inflicting on them a slight temporary hardship, but she was conferring a boon upon posterity.

A handful of people—they numbered only a hundred including the children—driven out of England on account of their religious views, landed at Cape

Cod on November 11th, 1620. They had had a tempestuous voyage, and to faint-hearted persons it might have seemed that they had escaped the horrors of drowning, only to die by the slower and more painful process of starvation. But the pilgrims were not faint-hearted. It is true that instead of making the mouth of the Hudson as they had intended, they had been driven by contrary winds on to the barren and forbidding coasts of Plymouth Rock; but they gave thanks for their preservation, and found comfort in the abundance of fish which the sea afforded. At first they won a bare subsistence by fishing; but in time their corn ripened and was harvested, the boys grew into sturdy young men, able to cultivate the land, and in due course prosperity rewarded their efforts.

The call of science surely must rank second only to the call of religion in our list of the motives which have led men to devote their lives to exploration. Science, however, is a mistress of modern times. She has had her devoted followers since immemorial days, but they have been few and far between, and obliged to make their passion a secret. She was not considered quite respectable; in fact, a liaison with science was regarded as synonymous with a liaison with powers of darkness. Men did not hold knowledge to be light in those days. On this account the few who courted her did so in fear and trembling, keeping the fruits of their researches hidden from all the world, lest they should be accused of witch-

craft and conspiring with the devil, and suffer mutilation or any of the savage punishments in vogue. Thus it is probable that many of the triumphs of modern invention were known, and perhaps actually experimented with, ages ago, but in such secret fashion that the ideas perished with the men who evolved them.

Nowadays, however, the world has no such scruples with regard to new and revolutionary projects. Public opinion has swung round completely. Not only will people supply large sums of money for expeditions to little-known lands, but there is a large and increasing class of persons who have only to be told a thing is new to have perfect faith in it. Every new thing is not faultless, or even desirable, but travel and exploration are always to be furthered. It is difficult to realize that even at the present time there are vast stretches of country to which white men have never penetrated, or, at any rate, from which no white man has ever returned. The great dark continent of Africa still holds unfathomable secrets in its heart; South America protects its hidden treasures with endless belts of swamps and forest, while Central Asia takes refuge in its barren deserts. The frozen Poles have been overcome—there is now less danger in a trip to the Antarctic than in a journey across Africa—because natural obstacles in the shape of bad weather and ice can be calculated upon, and preparations made to withstand them. At the Poles there is no savage human element to contend with; no disease that can-

not be met by wholesome living and feeding; no deadly insects multiplying by millions and carrying destruction wherever they go; no wild beasts nor loathsome reptiles. Hunger and cold there may be, but the man who sits at home determining "food values" and experimenting with methods of packing and compressing, guards the traveller amid the ice against the dangers of starvation.

So far we have only talked about travel by sea, because we have been following up the use of commerce in expanding travel, and the only means of land transport known to traders of early and mediæval times was the caravan. In the East the camel, and in the West the horse and his relations the ass and mule, represented the goods train of to-day. Wherever possible, heavy freights were sent by water. There were wagons, of course, but so heavy and clumsy were they, and roads so bad, that they were rarely used. The sledge was a far more popular conveyance, and you may see the sledge in use to-day in many a rough-country district. The development from tumbril to long wain and travelling carriage, and from long wain to coach, is a matter almost entirely dependent upon the improvement in road-making. So long as there were no roads there could be no carriages.

The greatest road-makers of all times were, of course, the Romans, but their very tenacity of purpose led them and their descendants into difficulties. The man in command said: "Let there be a road

from A to B", and from A to B that road had to go. Over hill and dale, through rock and across swamp, the road was laid, sometimes with extraordinarily steep gradients. Deviations were regarded with suspicion. Another of the tenets of the Roman road-maker was that no trees should be allowed to remain within a certain distance of the roadway, in order that robbers and highwaymen might not lurk among them to waylay travellers. Accordingly, when they came to a copse or patch of woodland, every bush and tree was felled, and left to rot where it lay, thus preparing long stretches of swamp for posterity to deal with.

The Romans and all their works passed away. The roads were neglected, and soon fell into bad order. Nobody travelled for fun, and traders could do all their carrying with the pack-horse. The real reason why the roads were so bad, and returned to their bad condition so soon after being mended, was that nobody knew how to make them well. That is why, from the time of the Roman occupation until the beginning of the nineteenth century, Great Britain had no good roads. The turnpike system involved travellers in the outlay of considerable sums in the course of a long journey, but since these sums were spent in making roads of loose round stones that would not and could not bind, the result obtained was really deplorable. It was not until Macadam and Telford introduced two dissimilar but perfectly reconcilable methods that the age of scientific road-making began. The bases of their systems were these: Telford

believed in making a strong, firm foundation of moderate-sized stones, to be covered with small gravel and well drained. Macadam thought more of the surface, and by covering his roads with broken stones which by their angularity would bind together, he could produce a surface impervious to rain and frost. Our modern method is a development of the two combined, and though we do not now have the foundations of our roads laid stone by stone by hand, as Telford recommended, yet more attention is devoted to them than Macadam considered necessary.

The improvement in roads led to a long chain of improvements in wheeled vehicles, a chain of which we do not yet see the end. Carriages no longer had to be strong and heavy to withstand the jolting to which they were subjected in the old days. Speed began to be fashionable, then necessary. Stage-coaches and post-chaises accelerated their services to a degree which a few years back would have been impossible. All kinds of light gigs and traps made their appearance upon the road, then came the bicycle, descended from the hobby-horse, and lastly the motor-car. With the coming of the locomotive the road suffered a temporary reverse, but now it is once more upon the winning side, and stronger than ever. The traction engine and its successor, the petrol tractor, now haul heavy goods by road all over the country; the mails go flying along in neat little vans in which sorters can work as they go; farm and dairy produce can be loaded at the farm door and carried off to

market straight away, without the delay of unloading again at the station, loading into the train, and then again loading into a cart at the end of the railway journey—operations which all mean time and labour, and consequently money.

The principle of the railway is as old, or almost as old, as the wheel. The Romans made railways of stone slabs, along which their wagons could rumble with comparative smoothness. Every quarry, mine, or other scene of heavy industry had its railway on which trucks might be drawn by men or horses, very long ago. But the idea of providing some mechanical means by which carriages could be propelled, with or without rails, was ever present in the minds of the followers of science, though for the reasons already stated few of them ventured to give expression to their ideas. We can give no name to the man who first discovered the power of steam. He must have lived far away back in the dim ages before dates, and was probably the first philosopher who ever watched a pot boiling and rattling its lid. You do not, of course, believe the pretty little story about James Watt and the kettle. The story is feasible enough, but must be applied to someone who lived thousands of years before Watt saw the light. The first man who made a really efficient steam carriage was Nicholas Joseph Cugnot, a French inventor, who, in 1770, built the machine which may still be seen at the Conservatoire des Arts et Métiers in Paris. It was quite a useful carriage, but what hope was there for a man at whom

one half of the public jeered, while the other half demanded that he should be shut up as a madman? Nevertheless, although he was obliged to forgo further experiments, the French Government gave him a pension, and the latter days of his life were spent in comfort, with the exception of another period of destitution occasioned by the vicissitudes of French politics.

William Murdoch was the first Briton to take up the problem of steam locomotion in a serious and practical manner. Murdoch was born in the county of Ayr in 1754, and for some years worked with his father, who was a millwright. But his was one of those rare spirits bound to rise in spite of the shackles of circumstance. The fame of James Watt, his fellow-countryman, penetrated even to Old Cumnock, and Murdoch set out to walk to Birmingham to ask for a place at the Soho Works. He was interviewed by Boulton, who immediately estimated his good qualities. Murdoch was given his job, and soon rose to a responsible position. For a good many years he was occupied in building and maintaining pumping-engines in the Cornish mines, and it was at some time during these years that he began to work at his model steam carriage. You may see this model to-day in the Birmingham Art Gallery. It is an uncouth-looking contrivance, carried on three wheels, the small front wheel being used for steering only. Spirit burning in an open vessel heated the water in the boiler.

For some time Murdoch endeavoured to keep his experiments secret. He only once ventured on to the high road, and that was in the dusk in a little-frequented Cornish lane. As luck would have it, however, the vicar of the parish happened to choose that particular spot for his evening stroll, and being firmly convinced that he had met with the devil, a scene was enacted in which Murdoch was probably as much frightened as the vicar. However that may be, he steamed no more upon the road, but contented himself with running his carriage within the shelter of four walls. In due time, as was bound to happen, the story of his exploits was brought to Boulton and Watt. The partners received the news with much misgiving, but from totally different causes. Watt had no faith or no interest in the possibilities of steam as a locomotive power, and was pained that Murdoch had not confided in him; while Boulton feared that if Murdoch succeeded with his models he would want to leave the firm, and he was too good a workman to lose lightly. Murdoch, however, had no intention of leaving his employers, and a little tactful persuasion on their part ended in his giving up his attempts at steam locomotion.

At the point where Murdoch relinquished the problem Richard Trevithick took it up. Trevithick was, of course, a Cornishman—Tre, Pol, and Pen, You may tell the Cornishmen—and a pupil of Murdoch's. Although Trevithick's history is one of disappointments, to him belongs the honour of first connecting

steam locomotives with railways. Before his time, railways had been used to facilitate horse traffic, and steam carriages had been made to run along a flat surface. The first steam locomotive to haul trucks along rails was that built by Trevithick for the Pen-y-darran ironworks in 1803. Following upon Trevithick's achievements come those of Blenkinsop, Hedley, and Timothy Hackworth, leading ultimately to the day of George Stephenson.

It is thus easy to see that George Stephenson has no claim to the title of "Inventor of the Locomotive" so often given to him. He was responsible for many improvements upon the locomotive designs of his predecessors. But, as far as the main ideas of steam locomotion were concerned, he worked upon the foundation built up by Murdoch, Trevithick, and the rest. He may, however, very fitly be called "The Father of the Railway", for it was solely to the efforts of his genius, and his amazing perseverance in the face of great obstacles, that the laying of our first railways was due. It is true that many fine engineering works had been carried out before Stephenson's time, but the difficulties with which he had to contend were peculiar, and he also encountered opposition—the most furious possibly ever directed against an innovator. His genuine inventions were few, the most noteworthy of them being his safety-lamp for use in mines.

Our great expresses capable of travelling forty-five miles in forty-three minutes—that is to say, of attaining, on a moderate run, a speed of nearly eighty miles

an hour—are not yet fast enough. More particularly, our suburban and local trains are not fast enough. A train that has to stop every mile or two miles never has time to get up speed, and consequently the service is slow and unsatisfactory. Such a service has results that are of much greater importance and more widely reaching than may appear at first sight. It is inconvenient and wastes time, which means money; but further than that, it has its worst effect in the congestion it creates in the neighbourhood of industrial centres. Whereas a fast-train service allows city workers to live at some distance from their place of business, a slow one enforces them to live near it. Thus anything which tends to accelerate travelling, especially in suburban districts, is of great benefit to the whole community, and not only to those who happen to make constant use of the railway.

Within recent years several developments have arisen which have been specially directed towards this very problem. The electrification of short lines of railway has become a special branch of the engineer's art, while rail motor-cars and engines driven by a petrol-electric or a steam-turbine electric motor have achieved great success. The desired goal of many inventors, however, has been the introduction of an entirely new form of vehicle. As you know well, if you start a perfectly smooth, well-oiled wheel running upon a smooth flat rail, it will keep on running until the friction of the air and the friction of the rail have brought it to a standstill. If you have four, six, or

eight wheels running along a pair of rails, the friction to be overcome is so many times greater. It was this fact which led experimenters to see what they could do with a truck or carriage running on one rail.

The first mono-rail of which we have any record was that built in Algeria by Charles Lartigue. He was in charge of an ordinary railway—on which the tractive power was not steam but mules—and he was constantly being put to the labour of digging his rails out of the sand. Naturally enough, this was a source of great annoyance, and after some time he determined to put a new plan into effect, and built a truck which should run on one rail. The story goes that the idea came to him from seeing camels loaded with heavy bags on each side. A similar kind of railway, on which steam-engines ran, was built in London by Mr. F. B. Behr in 1886, and was so well received that he built another in the west of Ireland which was running up to 1924.

The mono-rail of the future, however, is not that of Lartigue or Behr, but of Brennan. Louis Brennan, to whom we are indebted for the Brennan torpedo, is of Australian birth, and started life as a watchmaker. Sooner or later—at what period is immaterial—he came into contact with the gyroscope. Now the gyroscope has been studied and used by numbers of scientific men for a variety of purposes, but possibly it will never be experimented with for a more useful end than that which Mr. Brennan has reached. To perfect a conveyance which will travel in safety at

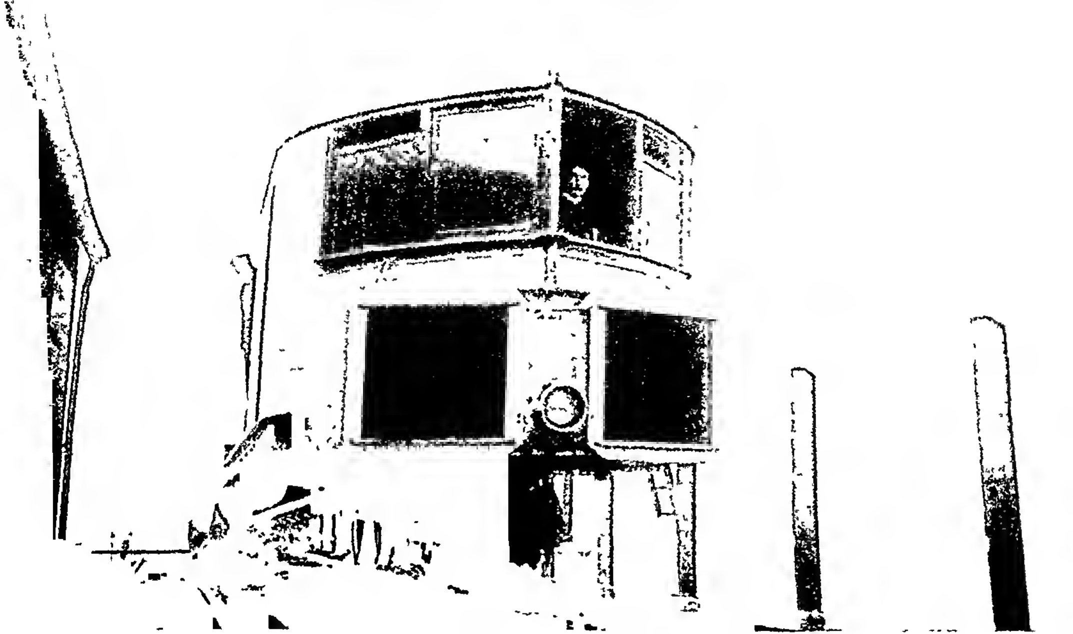

Photo Topical.

THE BRENNAN MONO-RAIL CAR

The car is standing still. The wonder of stability is rendered possible by the steadying power of the gyroscope

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a hundred and thirty miles an hour is surely a great triumph. That is what Brennan's experimental monorail car, running at Gillingham in Kent, can do.

Before we can attempt to describe Brennan's monorail, we must say a little about the gyroscope. This little instrument is one of the marvels of natural science. You know what it looks like in its simplest form—a wheel revolving on an axle supported in a frame. You know, also, that when the gyroscope is spinning on a table, you may tilt the table up or down, one way or another, but the gyroscope will absolutely refuse to tilt, and will preserve its upright position. Well, when Brennan came to examine the gyroscope, the idea that occurred to him was this—Why should not the gyroscope be used as a balancing agent?

This, in effect, is the principle of the Brennan monorail. Two gyro wheels revolve by electric power within a vacuum at a very high speed. They are placed side by side, but they revolve in opposite directions, this being necessary to maintain the balance when the car is turning corners. When the car tilts or the weight is displaced to the very slightest extent, the axles of the gyro wheels tilt accordingly, as they are bound to do in order to maintain the position of the spinning wheel. The rising axles act upon two steel plates, known as guide plates, and cause them to work in two ways. They not only transmit the pressure of the gyro wheels to the car, and so preserve the balance, but they also bring into operation a compressed-air engine which works for the same end

In spite, however, of its undoubted capabilities for high speed, and the smallness of its cost of construction, the mono-railway is slow in coming into its own. The reasons for this are not hard to understand. In the days of Stephenson the country was prepared for costly experiments, and, in fact, the slowest and most unreliable of steam locomotives was such a wonder that its defects, obvious to our eyes, were unnoticed by the ordinary observer. But to-day things are very different. We already have admirable railway systems and several methods of road transport. The country is covered by railways which have cost thousands of millions of pounds to construct and maintain; and the public, being more or less satisfied with things as they are, finds little interest in any scheme which involves a revolution of existing habits and ideas. Moreover, the objectors to the mono-rail on the grounds of its "unsafety" will be counted in droves and herds. The promoters of the mono-rail know well that, unless they would court disaster, they must carry on their work in obscurity until the day comes when they can produce the invention in a perfected form, for some special and arresting purpose. In this way its value would be proved before the sceptics had had time to formulate their criticisms.

CHAPTER IV

Ships and Shipbuilding

We of to-day cannot possibly realize the difficulties and dangers, real and imaginary, which attended the voyages of Columbus. Bad ships, bad provisions, bad weather, a mutinous and violent crew—all these are tangible enough. What we cannot appreciate is the terror of the unknown experienced by these superstitious men, and their perfectly natural dread of sailing on and on and on, until they died of thirst and starvation. Modern explorers, gallant men who face all the rigours of polar exploration in the interests of science, are assisted in every possible way by the fruits of the labours of scholars of all time—the feeding and equipment of a polar expedition is a science in itself, methods of packing and transport all have been brought to a pitch of high efficiency, and comforts and luxuries accompany the men who venture "farthest north" or "farthest south". But Columbus and the other early explorers were obliged to support life and do hard work under very different conditions. Bad biscuit and bad water, varied by fish and rain when they were able to catch them, formed their staple

diet. What wonder that they suffered horribly from scurvy and other dreadful diseases?

Yet we have not touched upon the most remarkable of the deficiencies of Columbus's equipment. Not only had he no charts and no maps to help him, no friendly vessels passing within hailing distance, no warning lights to guide him past the hidden dangers of the deep, but he did not know where he was nor whither he was bound. He could take his latitude, but had no means of finding his longitude. The only instruments he possessed were his compass, an astrolabe or a cross-staff, a fairly correct table of the declination of the sun, and a correction for the altitude of the Pole Star.

The finding of longitude was for centuries an impossibility. The following paragraph was written during the Armada period, and shows the state of the mariner's knowledge both then and at a much later date:—

"Now there be some that are very inquisitive to have a way to get the longitude, but that is too tedious for seamen, since it requireth the deep knowledge of astronomy, wherefore I would not have any man think that the longitude is to be found at sea by any instrument; so let no seamen trouble themselves with any such rule, but (according to their accustomed manner) let them keep a perfect account and reckoning of the way of their ship".

The "perfect account", however, could not be kept easily by mariners who had only the crudest methods

of testing the speed of a ship. The "Dutchman's log", as it was called, was used in very early days for this purpose. Something that would float was thrown out at the bows, and the length of time the ship took in passing it was observed. About the end of the sixteenth century it became customary to throw out a block of wood attached to a line. The length of line which went overboard while someone on board recited certain stanzas was measured, and from this the speed was calculated. Unfortunately no record remains of the words used in this operation. It is to be feared, however, that notwithstanding these ingenious ideas, the speed of a vessel was usually entered in the log by pure guess-work.

The cross-staff, such as Columbus might have used for taking his meridian, was an implement made of two light battens. The staff was generally an inch and a half square and thirty-six inches long. The cross, which fitted the staff exactly and crossed it at right angles, was just a little over twenty-six inches in length, to allow for the sights to be exactly twenty-six inches apart. Another sight was placed at the end of the staff. On the upper face of the staff was written a scale of degrees, while angles were indicated on the sides. The bearing having been taken by compass, and the sun nearing its meridian, the observer took up his position with the long end of the staff at his eye. Then he moved the cross until one end touched the horizon and the other the sun's centre, continuing thus until the sun dipped.

Columbus had a compass, of course. Nowadays the best compass in use is that devised by Lord Kelvin in 1879, and is known as Thomson's compass. It is a wonderfully delicate apparatus, the outer ring of aluminium being connected with the aluminium centre by threads of fine silk. The aluminium centre is supported by a sapphire, which in its turn rests upon an iridium point. But aluminium and iridium were unheard of in the days of Columbus, and his compass probably differed little in construction from that made hundreds of years before in China. The Emperor Ho-ang-ti, who lived and reigned in 2634 B.C., is reputed to have invented an instrument for determining the south, but no authentic record exists. In the year A.D. 121 a Chinese dictionary was compiled which defined Lodestone as "a stone by which an attraction may be given to a needle". We have no means of proving whether, as some think, Marco Polo brought the idea of the compass to Europe when he returned from his travels in Far Cathay, or whether a compass was invented independently by a European. The magnetic properties of certain ores were well known to the ancients, and it is certainly probable that the instrument was made by different races at the same time. One thing we know positively, and that is that no sea-going ships were built in China before 139 B.C., and a reliable compass was not a dire necessity to coasting vessels.

The history of steam navigation is, at its commencement, closely interwoven with that of the steam-

engine. It was, perforce, an offshoot of the labours of the pioneers of steam. Nevertheless the possibility of driving boats by means of a steam-engine was the subject of investigation absolutely independent of any devoted to locomotive or stationary engines, and has therefore a story of its own dating from the time when the power of steam was an accepted fact.

More than two hundred years ago a Frenchman named Denis Papin, to whom is due the invention of the piston, built the first steam-propelled boat. Papin was amongst the many brilliant men who were driven from France by the revocation, by Louis XIV, of the Edict of Nantes. His is not a happy story. After sojourns in England and Italy, in both of which countries he applied himself diligently to the study of mechanics and physics, he settled in Germany, where he succeeded in constructing the boat according to a long-cherished plan. The motive power was obtained by means of oars driven by a steam-engine. The next difficulty—one which has obstructed the progress of inventors in all ages and in all countries—was to obtain recognition of his invention. The following letters, preserved in the Royal Library at Hanover, show that in the case of Papin the obstacle was as insuperable as it has been in many others:—

"Dionysius Papin, Councillor and Physician to his Royal Highness the Elector of Cassel, also Professor of Mathematics at Manburg, is about to dispatch a vessel of singular construction down the River Weser

to Bremen. As he learns that all ships coming from Cassel, or any point on the Fulda, are not permitted to enter the Weser, but are required to unload at Münden, and as he anticipates some difficulty, although those vessels have a different object, his own not being intended for freight, he begs most humbly that a gracious order be granted that his ship may be allowed to pass unmolested through the Electoral domain; which petition I most humbly support.

"G. W. LEIBNITZ.

"HANOVER, July 13, 1707."

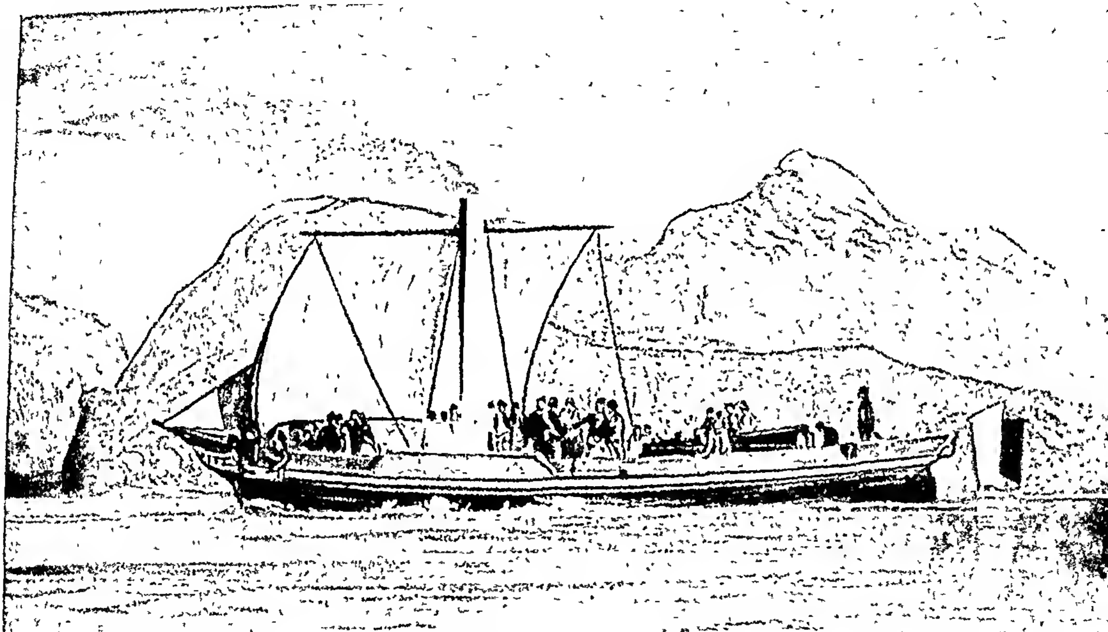
Now read the answer, at once final and evasive:—

"The Electoral Councillors have found serious obstacles in the way of granting the above petition, and without giving their reasons, have directed me to inform you of their decision, and that, in consequence, the request is not granted by his Electoral Highness.

"H. REICHE.

"HANOVER, July 25, 1707."

Thus poor Papin's hopes were defeated; and, to make matters worse, the river boatmen, believing that the new ship would injure their prospects, not only broke it into fragments, but attacked Papin himself. He, however, managed to escape, and took refuge in England once more. But this, his greatest effort, was also his last. Utterly disheartened, he died three years later, without the consolation of seeing any one of his numerous inventions accepted by the scientific world.



THE COMET

From a copy of an old painting in the Victoria and Albert Museum, London.

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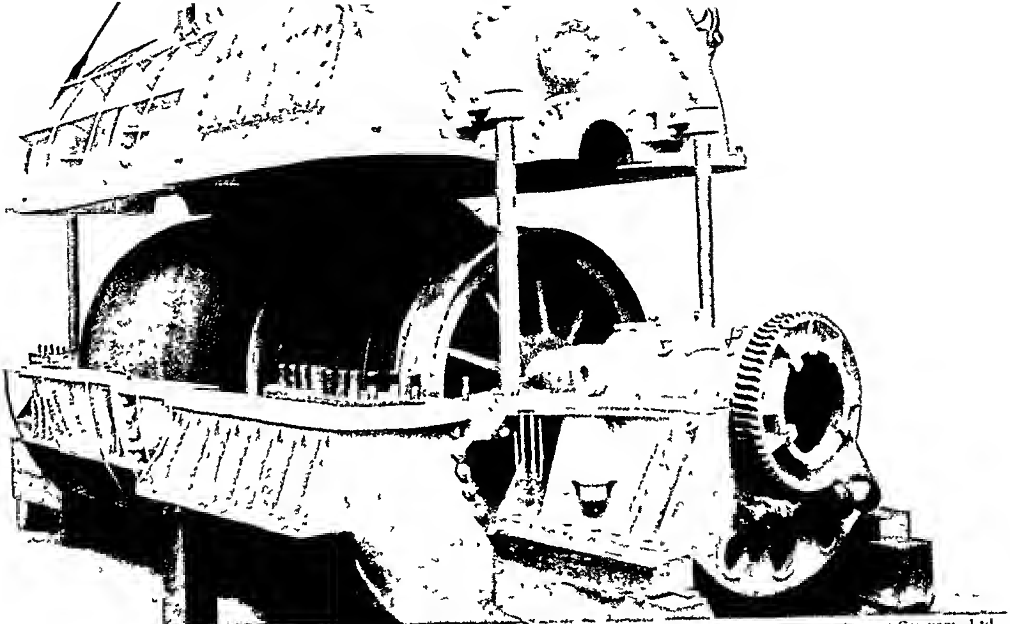

By courtesy of the Parsons Marine Steam Turbine Company, Ltd

MARINE STEAM TURBINE

The upper casing has been lifted and shows the huge drum with its thousands of blades.

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Jonathan Hulls, an Englishman, took out a patent for a steam-driven boat in 1736. The steamboat was to be used to tow vessels, and propulsion was obtained by wheels at the stern. His own description of it is as follows:—

"In some convenient part of the Tow-boat there is placed a vessel about two-3rds full of water, with the Top closed; and this Vessel being kept Boiling, rarifies the Water into a Steam, this Steam being convey'd thro' a large pipe into a cylindrical Vessel, and there condensed, makes a Vacuum, which causes the weight of the atmosphere to press down on this Vessel, and so presses down a Piston that is fitted into this Cylindrical Vessel, in the same manner as in Mr. Newcomen's Engine, with which he raises Water by Fire. . . . Thus I have endeavoured to give a clear and satisfactory Account of my New-invented Machine, for carrying Vessels out of and into any Port, Harbour, or River, against Wind and Tide, or in a Calm; and I doubt not but whoever shall give himself the Trouble to peruse this Essay, will be so candid as to excuse or overlook any Imperfections in the diction or manner of writing, considering the Hand it comes from, if what I have imagined may only appear as plain to others as it has done to me, viz., That the Scheme I now offer is Practicable, and if encouraged will be Useful."

There is no record that Hulls ever made a practical test of his idea, and the next experiments in steam navigation were carried out in America by William

Henry and John Fitch, and in France by the Marquis of Jouffroy and the Comte D'Auxiron. The French investigators actually built a boat which, at a public trial at Lyons, confirmed all the hopes of her designers; but the Government refused to help in the matter, and Jouffroy was so much disgusted and impoverished—D'Auxiron was dead already—that he gave up all his schemes. The Americans were more successful, and were, after much delay, granted money for the prosecution of their researches.

It was in Scotland, however, that the first really practical steamboat was built. In 1787, Patrick Miller of Dalswinton put forward a plan for a boat to be made with a double hull, having paddle-wheels placed between the two hulls, and a steam-engine to be used to drive the wheels. A ship was built according to this design by William Symington, who had previously succeeded in making some improvements in the steam-engine, and on its trial trip in 1789 made a speed of seven miles an hour. Symington's engine was afterwards stated by Miller to be "the most improper of all steam-engines for giving motion to a vessel", and nothing more was done in the matter. But the experiment had not passed unnoticed. About ten years later Lord Dundas, who was largely concerned in the Forth and Clyde Canal, commissioned Symington to build him a steamboat suitable for use on the canal. The *Charlotte Dundas*, launched in 1802, was the result, and her behaviour on her trial trip more than justified the expectations

of her builder. Unfortunately, the owners of the canal feared that the wash from steamboats would injure the banks, and forbade the furtherance of steam navigation. The Duke of Bridgewater had no such misgivings, and ordered eight boats for his canal from Symington; but before anything was done the duke died, and poor Symington's career was ruined.

The career of the steamboat, on the other hand, had but just begun. Henry Bell, he whom the Scots love to call "the father of steam navigation"—though the term is grossly unfair to Symington—had watched the exploits of the *Charlotte Dundas* with great interest. He had been for many years a firm advocate of the use of the steam-engine as a motive power for ships, and had applied to the Governments of Britain and the United States for help with his projects, of course without any effect. At length, in 1811, he set to work to build a ship on his own account. This ship, the *Comet*, was ready for use early in 1812. She had two paddle-wheels on each side, driven by engines rated at three horse-power. At that time, Bell and his wife were the proprietors of a hotel at Helensburgh, and the *Comet* was advertised as a passenger boat plying thither from Greenock three days a week. The *Comet* was by no means a financial success at first, but Bell had sufficient capital to enable him to face a temporary loss. After a time the confidence of the public was won, and by 1815 Bell had several steamboats performing regular

journeys. This permanently established the position of steam navigation in Great Britain.

In the meantime, America had been studying steam navigation assiduously. Her great rivers and vast lakes called for some rapid and reliable means of transport, and were, moreover, admirably adapted as experimental waters. Robert Fulton, who had learnt much from French and British engineers, and is also known as one of the initiators of the torpedo, built a number of eminently successful steamboats, beginning with the *Clermont* and ending with *Fulton the First*, the first steam battleship.

The introduction of ocean steamers must be ascribed to very natural causes. Trade was growing apace, cargoes were increasing, private travel was becoming more and more in favour. So far, America held the day. She had vast supplies of timber, and, more important still, her boatbuilders held the secret of speed. British boatbuilders could make stanch solid ships that would last many years and defy all the onslaughts of wind and wave, but they could not compete with their American rivals in point of speed. Now to a trader speed may be all-important. The famous clippers, racing home from the East with their precious load of fresh-gathered tea, were the express ships of their day, but they were liable to be driven out of their courses by contrary winds, and to lose days or weeks on the voyage. Something was wanted which could travel against the wind and tide. Into this breach stepped the British builder of steamboats.

He had comparatively little timber, but he had inexhaustible stores of coal and of iron. His shores were washed by sheltered seas; not so sheltered as to be invariably tranquil, but protected from the huge rollers of the Atlantic. Thus he could make profitable sea trips from one island to another while testing the capabilities of his new servant. The first transatlantic voyages made entirely by steam-power took place in 1838. Two British vessels, the *Sirius* and the *Great Western*, performed this feat almost simultaneously. The *Sirius* left Cork on 8th April, and the *Great Western* sailed from Bristol four days later, the two of them arriving in New York on 23rd April within a few hours of each other. The return journeys were made in eighteen and fifteen days respectively, against high winds. The *Sirius* did no more transatlantic work, as she was considered too small, but the *Great Western* continued in the service for six years, her record time for the voyage being twelve days seven hours.

In the meantime another revolution had taken place in shipbuilding. I mentioned a few lines back that the British shipbuilder had unlimited supplies of iron, and by the use of this material he regained the supremacy which the American, with his better designs and cheap timber, had wrested from him. The first iron ship was built on the Clyde in 1817 by a carpenter named Thomas Wilson, assisted by the local blacksmith. The *Vulcan*, as this plucky little boat was called, carried passengers up and down the Forth and

Clyde Canal for nearly three-quarters of a century, but she did not attract such widespread notice as did the second iron boat, which was also the first iron steamboat. This was the *Aaron Manby*, named after her builder, an engineer of the Horsley Iron Works. Her first trip was from London to Havre, thence to Paris, where she was greeted with astonishment. Her success paved the way for the defeat of the Americans. The strongest and stanchest of wooden boats could withstand the strain of steam-engines only a few years; indeed, the East Indian sailing vessels could make only six voyages with safety. Now, therefore, when British engineers began to build iron ships that would last a lifetime, the wooden ship was doomed. The Americans, moreover, were so well accustomed to using their timber for all purposes that they never thought of looking for iron-fields, and so outstripping the Briton once again.

It was not, however, until the day of the American clipper, that is to say, about 1850, that the iron ship came into her own. The British traders were bound to compete with the Americans, and since they could not do so with wooden sailing ships, they would with iron steamships. Within ten years, five-sixths of Great Britain's merchant fleet was built of iron, and the Americans were still wondering what had happened to their trade, and trying to blame the Civil War for their losses.

The next important change in material was brought about by French experimenters who, in 1873, began

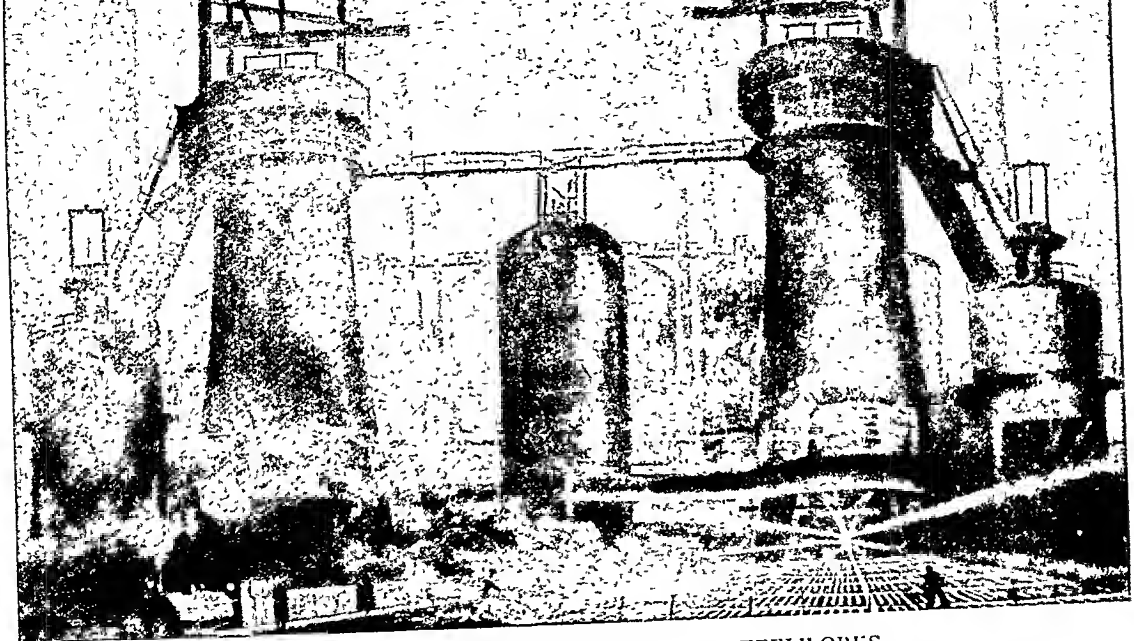
to build ships of mild steel. Two years later the Siemens Steel Works, of Landore in South Wales—"lovely Landore", as it is satirically called, the greyest, most forbidding place in the Principality—perfected a new process for producing mild steel, bringing its cost so low as to be within the reach of every shipyard. Mild steel has points of superiority over iron for shipbuilding purposes similar to those of iron over wood. It is lighter and stronger, can support heavier weights and harsher treatment, and, while being cheaper to build, will do more work, and consequently bring in more money for the owner.

The best of our modern piston engines suffer from a great defect. For nearly all purposes the up-and-down movement of the piston has to be converted into a circular movement, and in this way a certain amount of energy is wasted before any work can be done. Yet although they recognized this defect and the waste it caused, our engineers all agreed that it could not be remedied. "Nothing can be done," they said, "so it's no use trying, and we're all quite satisfied with things as they are."

Fortunately there arose in the midst of the pig-headed engineers a young man with a mechanical mind and a scientific training. He held the view that to devise a steam-engine with a minimum of waste was not opposed to science, and that there seemed to be no reason why it should not be done. This young man was Sir Charles Parsons, son of the Earl of Rosse, and pupil of Sir Robert Ball. Science, so to

speak, was his daily meat, while mechanics were his chosen relaxation. Thus, when at the age of twenty-two he entered the Elswick works, his mind was not only alive and ready to acquire whatever was taught him, but ready also to lead him on the way to new discoveries of his own. He had realized for a long time that the steam-engine stood in need of improvement, but after some years of partially successful endeavour he came to the conclusion that nothing could be done with engines built on the existing plan, and that he must begin all over again and invent a new steam-engine.

Sir Charles laid the foundation of his efforts upon the principle of the water-wheel; but whereas the velocity of water had been perfectly understood for hundreds of years, no one had ever troubled to determine the velocity of steam. Consequently that was the first problem which faced Sir Charles, his idea being that a wheel might be driven by jets of steam acting upon tiny blades projecting from it. His first engine, built upon these lines in 1884, may be seen in the South Kensington Museum. It was intended to work a dynamo, but unfortunately no dynamo would consent to be worked by this new motive power. The piston engine could generate electricity by causing a dynamo to make 1500 revolutions a minute, but the Parsons engine made its dynamo revolve at more than ten times that speed, with the result that all self-respecting dynamos meditated discharging themselves around the room in fragments.



THE CASTING OF IRON AT A BRITISH STEELWORKS

The charging of the blast furnaces shown in the picture goes on day and night The white hot molten metal is run off into the sand moulds, where it cools and becomes solid "pig-iron".

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Moreover, the little turbine was very extravagant. But Sir Charles had no intention of giving up the struggle, and, since no existing dynamo would stand the strain, he made one that would, and also set himself to the harder task of teaching his turbine economy. After four more years of patient toil he achieved his end, only to be rewarded by a grievous disappointment. The firm with which he had been associated for some years severed his connection with them, but refused to allow him any rights in those of his inventions which they had taken up. He was thus debarred from going any further with the engine he had just perfected, and with a heavy heart, for which a rapidly lightening purse was no kind of compensation, he began to try to build a new engine.

Five weary years followed, during which he proved to himself, no less than to the world, that his first turbine was the one efficient design, while he suffered all the humiliation of the unsuccessful inventor. But at length brighter days dawned, and he was able to recover his interest in his original model. Friends crowded round him once more, and his turbine was soon a theoretical success. Yet the first turbine-driven boat was not a success, and the reason for its failure produced an entirely new problem for the scientists to solve. This problem is now known as "cavitation". The propeller of the *Turbinia*, as this first little vessel was named, spun round and round at the rate of 1500 revolutions a minute, but the resulting speed of the vessel itself was extraordinarily

steamships is so much waste space, and in similar convenient places in locomotives, and only occupies a quarter of the space required by coal. Oil fuel has the additional advantage of being very cheap, as crude oil, tar, and tar-oil can all be consumed in the oil-engine with excellent effect. What makes it seem so intricate is the mechanism of the four-stroke cycle, and the various devices which control the supply of fuel in such a way that there is a minimum of waste of energy and space.

With the first movement of the piston the valve which admits air opens, and the cylinder in which the piston moves fills with air. The upward movement of the piston follows, but as the valves are closed the air cannot escape, and so is compressed to a high degree. At the moment when the piston is at its highest point, very finely sprayed oil enters the cylinder. The compressed air has attained a very high temperature, and the oil catches fire upon touching it. With this the air expands again, and forces the piston downwards. As the piston reascends the gases produced by the combustion are driven out through the exhaust valve, and the process then begins again.

Now although this is easy enough to understand, it was by no means easy to devise the mechanism which performs it. Naturally, the oil which is sprayed into the compressed air needs to be driven by some very powerful means, and the difficulty was to provide sufficient power without greatly complicating the

engine. In the end Dr. Diesel designed an attachment worked by the piston shaft, which compresses air to force the sprayed fuel into the compressed air in the cylinder, while a second attachment operates the mechanism which fills the cylinder with air at the beginning of each process.

Dr. Diesel's was the first practical oil-engine, but based upon his designs, though differing from them to a greater or less degree, many models have been built. The possibilities of the oil-driven locomotive, and even more of the oil-driven ship, are so alluring that scientists and mechanics alike are anxious to see them firmly established in the world's scheme of transport. A much-simplified type has been produced by a British engineer, which works by two strokes instead of four. The time cannot be very far distant which will see the oil-driven ship doing all the work now done by grubby old King Coal.

CHAPTER V

Metals and Tools

In the chapter dealing with ships we saw how developments in shipbuilding have been largely a matter of material—how the iron ship was capable of far more than the wooden ship, and the steel ship surpassed them both in usefulness. Shipbuilding, however, is only one of the many industries which have been changed for the better, if they have not actually been made possible, by the rise of new materials. In the sixteenth and seventeenth centuries the industry of iron smelting itself tended to die out in England, for the all-sufficient reason that the supply of timber was running short, and to smelt without fuel has always been an impossibility. Great Britain being an island, her ships were her first consideration, and during the reign of Queen Elizabeth it became necessary to pass laws reserving timber for shipbuilding, since the iron smelters were using it up so fast. In these circumstances many ironworks had to close, and English iron used to be sent to Ireland—a long journey in those days—to be smelted. Coal was used for smelting iron for part of the seventeenth century by a man named

Dudley, but although his process was economical and successful, he did not prosper. The times were difficult, and Dudley, being a Royalist, could get no support from Cromwell's government. Like so many of the heroes with whom we meet in this book, Dudley died poor and disheartened. Nobody knew exactly how he had managed his furnace, and so ended the first trial of smelting with coal.

Not until the eighteenth century did the man arrive who was to revive the dying industry and bring Great Britain to a point of supremacy as an iron-producing country. This was Abraham Darby, who in his furnace at Coalbrookdale burnt coal from the year 1713 with excellent results. Other ironmasters were hard to convince, but about 1750 coke was introduced as a fuel. Immediately an enormous difference appeared in the working of the furnaces. Expenses went down and profits went up, and in a very short time the use of coke as a fuel for smelting became general.

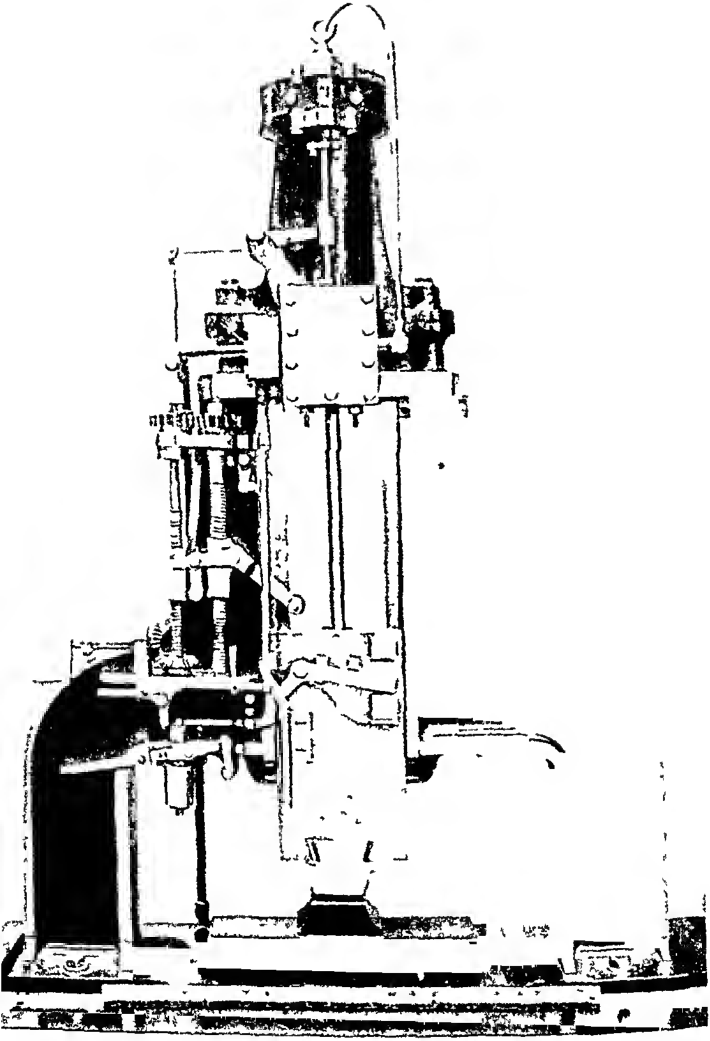
The story of iron is an apt instance of the manner in which a development in one industry or science leads to development in another. Iron was necessary to existence, therefore a fuel had to be found to smelt it. The fuel chosen being coke, coal must be obtained in ever-increasing quantities. The coal mines having an uncomfortable habit of filling themselves with water and drowning the miners, some means had to be found of keeping them dry. Hand pumps were no good, and so James Watt worked at his model of a steam pumping engine until he made it

efficient. From that point we may trace the evolution of modern motive power and transport.

It is also an instance of the liberality of Nature in certain countries. The coal which is essential for the proper smelting of iron nearly always exists close beside it in the earth, as does the limestone which is used in the industry. Better still, these three natural products, which provide between them the most important of all metals, are always found, in Great Britain, within easy reach of the sea or a tidal river. These are all matters of immense importance, since they lessen expense and facilitate transport to an extraordinary degree.

What, then, is this process of smelting of which we have been talking so much? Well, you must know that iron in its raw state—that is to say, the state in which it is taken out of the ground—is mixed up with a lot of other earthy substances. The coal-miner digs a piece of coal out of the ground, and it can be taken away and put on the fire without any further trouble. In the case of iron, however, although we could forge a tool from a lump of raw iron, it would not be a very serviceable one, on account of the other minerals and the clay embedded in the iron. The first thing the iron-worker has to do is to remove all these foreign substances.

To begin with, the freshly-dug iron is loaded into trucks and carried off to the roasting kiln. This is a chamber built of fire-brick, at the bottom of which a small fire of coals is lighted. Upon the fire is



NASMYTH'S STEAM HAMMER

From a photograph of a model in the Victoria and Albert Museum, South Kensington, of the original steam hammer invented by James Nasmyth

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spread a layer of ore, which soon becomes heated. When it is red-hot another layer is spread upon it, and so on until the kiln is full. Meanwhile the fire has burnt itself out, and the ore is taken from the kiln as it cools, layer by layer. By this means water, carbon dioxide, and sulphur are extracted from the ore, which is now ready to be smelted.

Smelting is carried on in blast furnaces. The story of the growth of the blast furnace is interesting, as it is a story of a complete revolution in one particular branch of industrial theory and practice. A little more than a hundred years ago—in 1792, to be exact—was born James Neilson, the man who entirely changed the principle of the blast furnace. He was the son of very poor parents, but somehow the money was found to send him to school until he was fourteen years old. At that time the iron-smelting industry was in its infancy around Glasgow, where Neilson lived, and he took a great interest in the huge works, which were just beginning to add largely to the importance of the city. Shortly after he attained to manhood the Glasgow Gasworks were started, and Neilson, who had previously been an engineman in a colliery in Ayrshire, was appointed foreman of the new undertaking. But the furnaces were his best friends. He could not keep his thoughts from them, and his scanty spare time was occupied by experiments and calculations relating to them.

At the beginning of the nineteenth century the chief difficulty of the iron-workers was to keep the

blast cold. They packed the tuyères in ice, or surrounded them with cold water, for this end. Neilson, however, had conceived the notion that the cold blast was extravagant, and that far better results could be obtained by the use of a blast of hot air. Of course, nobody would listen to him. We are prepared by now to hear of the cruel disappointments of our inventors and innovators. But success came to Neilson at last, and after years of weary waiting he was actually allowed to try his plan at the Clyde Ironworks. The result came as a complete surprise to everyone but Neilson. He knew what to expect from his hot blast, but when the incredulous ironmasters found that the same amount of fuel operated by the hot blast smelted half as much ore again as the cold blast, they were bound to admit the efficacy of his plan. The use of the hot blast, and the consequent lessening of expense in smelting, caused tremendous activity in the industry. Huge new towns, of which Middlesbrough is a shining example, sprang up and prospered wherever ironstone existed in large quantities.

The story of steel is interesting on its own account, but far more interesting are the stories of the two wonderful men whose names are connected so intimately with the modern aspects of steel-working—Karl Wilhelm Siemens and Henry Bessemer. The inventions of these two men have really created the modern steel industry, for they have made it possible to produce good steel at a low cost. Of

course, the art of steel-making was well known in ancient times. Swords, knives, and daggers of steel, as well as other articles, were made by the ancient Greeks and Romans. But until Bessemer began his experiments and brought his converter to perfection, the manufacture of steel was so costly that the purchase of steel cutlery and weapons was out of the question for poor people. Since steel has become cheap the uses to which it has been put are almost beyond calculation, and it has been instrumental in cheapening and simplifying our daily life to an extraordinary degree. We have only to mention steel saucepans, steel bicycles, steel houses; and then by way of contrast to throw our minds to the steel girders of some gigantic structure, and back again to the tools that make and shape these things, to see what a vast number of everyday things have been given to us by steel. And they are not steel merely, but steel in an infinite variety of forms, each of which has been developed by science for a special and particular use. Within the last twenty years there have been vast strides in metallurgy. One hears little about them; but the air-pilot, at least, knows that it is to the metallurgist, more than to anyone else, that he owes his present security. He knows, for instance, that without tungsten-steel he could not safely run his engine for hours with the exhaust-valves continuously red hot; and that the recently developed alloys of steel and aluminium help him in many ways. To take an example, duralumin is nearly as strong as mild steel

and not much heavier than aluminium; while magnalium, an alloy of aluminium with magnesium, is actually lighter than aluminium, and much stronger.

Karl Wilhelm Siemens, better known as Sir William Siemens, was an inventor of extraordinary versatility. He was the youngest of four clever brothers, born at Lenthe, in Hanover, 1823, who, their father dying while they were young, were obliged early in life to fend for themselves. The eldest brother, Ernst, had invented, while in prison, a method of gold-plating, and in 1842 he sent Karl to England to sell his process. The great English firm which Karl approached was not encouraging, and declared that it already held a patent for such process, of which Ernst's method was an infringement. Inwardly dismayed, Karl replied boldly that his brother's process was performed by a new and special kind of battery, and after some more conversation the firm agreed to consider the matter further if Ernst would send them particulars of his battery. Karl went home and wrote a gloomy letter to his brother, to which Ernst replied characteristically by sending specifications of the required battery. He had set to work to invent the necessary instrument as soon as he had received Karl's letter. The tangible result was a fee of £1400, a sum of the greatest use to the struggling Siemens family.

Some years later another brother, Friedrich, built a new kind of regenerative furnace, with the help of Karl, who had meantime settled in England. It was

this furnace which proved such an unqualified success when applied to steel-working.

Besides the matter of steel, there are numerous ways in which the metallurgist has helped the inventor and the manufacturer in recent years. Many metals which used to be too expensive or unsuitable to work are now in constant use.

Within the scope of this chapter we must treat of a class of men who, although they were not metallurgists in the strict sense of the word, nevertheless produced work of the highest importance to industry and commerce. These men were the inventors and perfecters of the great machine tools which are used in so many branches of mechanical work to-day.

Henry Maudsley was the first of the tool-makers. Before his day the best workshops were meagrely equipped with few and clumsy appliances. Everything had, of course, to be worked by hand. The lathe, of exactly the same pattern as that which had been in use for some hundreds of years, a few drills, and the ordinary kinds of hammer, chisel, saw, adze, and similar tools, constituted the whole of the mechanic's stock-in-trade. Duplicate articles, or parts of machinery, had all to be made separately and shaped by the workman's hand and eye, consequently a considerable variety in size and shape was unavoidable. Only the very best workmen produced anything approaching accurate work. It was this very difficulty which obtained for Maudsley a place in the works of Joseph Bramah, the great locksmith.

Bramah had invented a lock which was practically "unpickable", but he had no workmen sufficiently skilful to make it for him. Accordingly he had to apply to all the mechanicians he knew for advice in the matter, and was given, amongst other names, that of Maudsley, who had by that time won golden opinions from the officials at Woolwich Arsenal where he was employed.

Maudsley worked for Bramah for eight years, adding materially to his master's prosperity but comparatively little to his own. He not only improved the famous lock, but he invented tools to make it with. Then, when Bramah turned his attention to the hydraulic press, Maudsley invented his "self-tightening collar", which allowed the piston-rod to work in the gland without letting any water escape from the cylinder—a point which previously had proved an insuperable difficulty. But his most important achievement while with Bramah was his construction of the slide-rest for use on the lathe. Maudsley had to spend much of his time in duplicating small parts, and he found that with the existing lathe his work was apt to be irregular and unreliable. In such work accuracy was all-important, and Maudsley determined to find some means of ensuring it. The slide-rest which he eventually produced held the tool in the desired position against the work revolving on the lathe, and the operator had only to turn the screw handle to perform the necessary adjustments.

James Nasmyth, who was a pupil of Maudsley's, writes thus of the value of the slide-rest:—

"It is not, indeed, saying at all too much to state that its influence in improving and extending the use of machinery has been as great as that produced by the improvement of the steam-engine in respect of perfecting manufactures and extending commerce, inasmuch as, without the aid of the vast accession to our power of producing perfect mechanism which it at once supplied, we could never have worked out into practical and profitable forms the conceptions of those master-minds which, during the last half-century, have so successfully pioneered the way for mankind.

"The steam-engine itself, which supplies us with such unbounded power, owes its present perfection to this most admirable means of giving to metallic objects their precise and perfect geometric forms. How could we, for instance, have good steam-engines if we had not the means of boring out a true cylinder, or turning a true piston-rod, or planing a valve face? It is this alone which has furnished us with the means of carrying into practice the accumulated results of scientific investigation on mechanical subjects."

At last the day came when Maudsley, with perfect justice, asked Bramah to increase his wages. It is hard to account for the niggardly spirit which made Bramah refuse, but he paid dearly for his folly in the end. Maudsley, knowing full well that his abilities were worth more money than he was earning, left

Bramah and opened a shop of his own. He had a hard struggle at first to make ends meet, but before long he acquired such a flourishing business that he had to move into larger premises.

It was at this period that Maudsley made the decisive step towards prosperity by his association with Brunel. Brunel had been commissioned by the Navy to design machinery for block-making, and although he had drawn up elaborate plans his knowledge of practical mechanics was so vague that he was unable to undertake the practical construction of the machines. In his dilemma he went to Maudsley for help, with excellent results. Maudsley built the whole series of intricate machines, according to Brunel's designs, and built them so well that they remained in perfect working order for more than fifty years. Every tiny part of the forty-four machines was made in Maudsley's own works and under his own immediate supervision, which is a guarantee that every part approached, if it did not reach perfection. No work could have attained such a degree of soundness and accuracy before the invention of the slide-rest.

It is impossible to enumerate the tools invented by Maudsley; indeed, it is doubtful if a complete list could be made, for many of his inventions were either not patented at all, or were patented not by Maudsley, but by some unscrupulous person who had stolen his ideas. One very important tool devised by him we may mention, and that is the apparatus for screw-cutting. Before that time every screw had to be hand-

cut and the threads turned according to the sweet will of the cutter. Maudsley's machine produced threads of a uniform size, which would all fit a standard nut. But even more valuable to mankind was the excellence of Maudsley's workshop as a training school for mechanics and engineers. Not a few of the men who passed through his hands subsequently stood before the world as engineers of the highest order, who had learnt from their master to be satisfied with nothing less than the best of workmanship, design, and material.

Foremost amongst Maudsley's pupils we find James Nasmyth. His name is familiar to the whole world on account of the great steam-hammer which he designed, and few people know anything else in connection with him; but his biography is full of interest. He was born in 1808, his father being Alexander Nasmyth, the famous Scottish artist, from whom he inherited strong artistic tastes, as well as a fondness for mechanics. He attended the Edinburgh High School for some years, but he did not shine as a scholar. He was passionately fond of certain subjects, but the classics did not interest him in the least degree, and his chief claim to school success lay in his ability to make beautiful tops. He left at the age of twelve, continuing to work at home with his father and studying chemistry with a friend. His father possessed a well-equipped workshop, and there Nasmyth spent much of his time, making all his own chemical apparatus, in addition to many tools and

mechanical contrivances. After some years he began to build engines, one of his first productions being a little steam-engine to work the mill which ground his father's colours. In work of this kind, which soon won him local fame, and the study of drawing and the excellent lectures of the new Edinburgh School of Art, he occupied himself during the years which most young men devote to games and Greek verse. But the time was coming for him to go out into the world, and he made up his mind that he would seek employment in Maudsley's works.

There were difficulties in the way of this plan. His father was not rich, and could not afford to pay a large premium for his son to enter Maudsley's as a pupil. However, Mr. Nasmyth wrote to Maudsley, with whom he had a slight acquaintance, asking on what terms James could be received in the works. To this letter a disappointing answer was received to the effect that Maudsley & Field no longer accepted apprentice pupils, having tried them and found them unsatisfactory. But James and his father were not disheartened. Armed with a beautiful model engine—James's best piece of work—and some of his most carefully executed mechanical drawings, they set off for London in a coasting steamer.

Maudsley welcomed his visitors kindly, but made it quite clear that his rule not to receive pupils was unalterable. To the great delight of both father and son he offered to take them over the works, and during the tour he became more and more impressed with

the capabilities of James. When on returning to the office James produced the engine and the drawings, the matter was settled without further discussion, Maudsley saying that any question of premium was quite unnecessary, and that James could begin work at once as his private assistant.

The training Nasmyth received with Maudsley would have been helpful to any man of moderate talents, but to one of his fertile brain and alert perceptions it was of incalculable value. In 1830 Maudsley went to Berlin to superintend the erection of certain machinery and incidentally to enjoy himself. While there he examined the apparatus at the Royal Observatory, and on his return fired Nasmyth with some of his own enthusiasm to make a telescope. Nasmyth suggested several useful modifications in Maudsley's ideas, and the telescope was a great success. It was this circumstance which probably led to the interest in astronomy evinced by Nasmyth in his later years. Soon after this incident Maudsley died, and within a few months Nasmyth left the firm in order to start in business on his own account.

After some deliberation Nasmyth decided to settle in Manchester. He began in a small way, but orders were soon flowing in, chiefly for his self-acting machines. Before long he had to find larger premises, and found an almost perfect position on the banks of the Bridgewater Canal at Patricroft. Here he designed one of his most valuable contrivances, the safety foundry ladle, which could be handled

easily by the workmen without any of the danger involved in the use of the clumsy old pattern ladle. Molten metal is terrible stuff, and fatal accidents to tippers were frequent. Nasmyth's invention changed all this, for he devised a cauldron which could be worked smoothly and easily by one man. He was far too generous to patent an idea of such great service to the world, but sent his specifications round to the different foundries, and his ladle soon superseded the other kind entirely.

Nasmyth's factory grew and prospered, for in those early days of the railway era work of his kind was plentiful, and he was well able to make special machines for special subjects. The Great Western Railway in particular kept him busily employed in building locomotives. Later on, the same company approached him upon another matter. They already had a large steam vessel—the *Great Western*—in service, and they had decided to build another even larger, which was to be called the *Great Britain*. They wished Nasmyth to undertake the construction of the machinery to be used in connection with it. Terms were soon arranged, and Nasmyth set to work. All went well until the task of forging the paddle-shaft began. The great size of the ship demanded a huge paddle-shaft such as had never been seen or heard of before, and no hammer and anvil in the world were capable of achieving such a task. The engineer in charge of this part of the work wrote Nasmyth a despairing letter asking for his help and

advice. It was a problem such as Nasmyth loved. Sitting down with his sketch-book in his hand, he began to trace out the proportions of a machine which should be able to perform so formidable an operation. In a flash of inspiration the whole thing appeared to him—the huge block of metal which should be the hammer, the great framework supporting it, the engine to drive it, the delicate mechanism for guiding and controlling it—all became clearly visible to him. The Great Western Company was delighted with the idea; but before the construction of the new tool had begun it was decided to use screw propellers instead of paddles for the *Great Britain*. Nasmyth contented himself with sending drawings and specifications of his invention to the great iron-workers of the country, but as the trade was then passing through a period of great depression nobody sent him any orders.

The hammer remained, accordingly, a roughly executed design in Nasmyth's sketch-book. There is no knowing whether it would ever have materialized had not a certain M. Schneider, of the Creusot Ironworks, paid a visit to Nasmyth's factory. The all-important sketch-book, wherein so many ideas were delineated, was always shown to visitors whom it was wished to honour, and on this occasion M. Schneider and his mechanical manager were both allowed to look through it. Naturally the sketch of the hammer provoked comment, but nothing of any significance was said on either side. Between two and three years later Nasmyth paid a return visit to the Creusot works,

where he was astonished to find a steam-hammer exactly according to his pattern in brisk working order. Whatever he may have thought of the deliberate copying of his idea, we can be sure that he experienced a thrill of justifiable pride at the sight of the efficiency of the tool he had designed. On his return to England he took out a patent for the hammer, which soon became a necessity in every large ironworks. Nasmyth also adapted his hammer for use in pile-driving, with excellent results.

Joseph Clement was about thirty years older than Nasmyth, and had left Maudsley before Nasmyth's time. The son of a poor hand-loom weaver, Clement early showed a turn for mechanics and for drawing, both of which tastes he cultivated when he was not slating roofs. Slating, however, did not please him as a profession, and he soon left it to take up mechanical work. He worked so well and lived so sparingly that before he was thirty-five he had saved a hundred pounds, with which he determined to go to London. He obtained work with Bramah; but although Bramah had learnt the value of generosity by the loss of Maudsley, his sons had not, and when they succeeded to the business on the death of their father they dismissed Clement, although he had proved himself an exceptionally good workman. Clement then went to Maudsley, with whom he did not stay very long, being desirous of entering into business on his own account. All these years he had kept up his drawing, and now this gift was to be of great service

to him. The reputation he had made for himself for thoroughness and capability led the Society of Arts to employ him to make drawings of intricate machinery. To help him in this work he invented implements for drawing straight lines and ellipses, these devices being considered so valuable that the society awarded him a gold medal. Like Maudsley, Clement devoted most of his energies to the making of machine tools, and made a great many further improvements in the lathe.

The work of Sir Joseph Whitworth differs greatly from that of the three engineers we have just mentioned, but it was not any less important. The object to which his attention was directed first was the perfection of some method of ensuring a plane surface. In many machines, or parts of machines, an absolutely true surface is essential. When there was no means of obtaining it or testing it, an otherwise excellent machine might be spoilt by a very slight unevenness in some vital part. At this time the only tools for smoothing and levelling surfaces were the hammer, the chisel, the file, and the face-plate. The article which required smoothing was covered with a thin coating of some moist colouring matter, and then pressed against a pattern surface. The inequalities were thus made obvious, but such a method was extremely crude and inexact. Sir Joseph Whitworth changed all this in 1830 by his invention of a planing machine which was capable of cutting a perfectly straight edge upon a length of forty feet. This

achievement was only the beginning of his activities, and he next turned his attention to the possibilities of measuring by machinery, rightly appreciating that an inaccuracy too small to be measured by ordinary methods might well be a source of trouble in a delicate machine. He devised a contrivance so sensitive that it could register even a millionth part of an inch. This may sound incredible, or if credible, at any rate unnecessary, but no inaccuracy is too small to be unimportant in the construction of tiny mechanisms.

Another very valuable piece of work for which Whitworth was mainly responsible was the standardization of screws. Maudsley, as we have seen, had already effected a great improvement in the practice of screw-cutting, but Whitworth, by producing machine-cut dies for screws, ensured their uniformity. Following up this idea he persuaded cotton-spinners to use machine-made spindles. No two hand-made spindles were alike, and when a spindle broke, as they often did, it was a tiresome matter to find a new one to fit the bobbin. Machine-made spindles, however, whether you want them by the hundred or the million, will all be exactly alike and suitable for any bobbin of its size. Something of Whitworth's activities may be gauged from the fact that from 1834 to 1849 he took out fifteen patents, mostly for machine tools. In those days it cost, roughly, £500 to take out a patent, so that we may be sure he only patented his most important inventions.

The greatest work of Whitworth's life was in connection with matters differing widely from these we have mentioned. It is hard to imagine two things in greater contrast than spindles and guns. Like everything else at that time rifles were made by hand. Consequently they were all different. One might be excellent, and another might be useless. When the Crimean War broke out there was an instant demand for large numbers of guns, but the factories which only employed hand labour were quite unable to meet it. In this dilemma the Government asked Sir Joseph Whitworth to supply drawings and plans for rifle-making machines. This, however, was a task needing special research and experiment, and owing to one delay after another it was March, 1855, before he was able to start work. For two years he studied the problem of the rifle with the utmost devotion, making practical tests and experiments on a shooting-range which he had had built for the purpose. The results of his labours were of incalculable value. Not only did they help him in the construction of his rifle-making machinery, but they taught him a great deal of the science of ballistics. Ballistics is the name given to the study of the ways of projectiles, and a very difficult and complicated science it is. Comparatively little attention had been given to it before, but Whitworth made such startling discoveries that with pardonable pride—and ignorance—he called his new projectile the "anti-war shell".

The principle of the rifle is so well known that

there is no need to describe it here. The existing Enfield rifle, at the time that Whitworth began his experiments, had a cylindrical bore making a complete turn in twenty-seven inches. Whitworth's product had a hexagonal bore with rounded corners, causing the projectile to turn once in twenty inches. At a public trial of the two rifles Whitworth's proved itself incomparably superior. His success, however, was not merely a question of the excellence of the weapon. He had improved the cartridge to be used, and the gunpowder employed in making it.

He now turned his attention to the making of heavy guns and projectiles, producing the anti-war shell already mentioned, which he believed to be so drastic in its action that no army could stand against it, and consequently warfare would soon become a thing of the past. But at the outset he experienced a serious check, for, whereas steel was too brittle for his purpose, iron was not strong enough to stand the enormous strain to which his projectiles subjected the barrels of his guns. This difficulty he set himself to remove by improving the quality of steel. Sir Henry Bessemer had succeeded in his experiments in steelmaking, but even the best steel produced by his methods was not good enough for Whitworth. First of all he enquired into the source of the trouble, and found it to lie in the fact that Bessemer steel, instead of being absolutely solid, contained countless tiny cells filled with gas. The problem Whitworth had to solve was the expulsion of all gases from the molten

steel, and it was no easy one. It is said that for nearly three years he made on an average twenty experiments a week, all with reference to the improvement of steel manufacture, in addition to his manifold labours in other directions. At last he established the fact that all gases could be discharged from molten steel by a pressure of six tons to the square inch, but he was still little nearer his goal, for he had no means of applying such a pressure to fluid metal. If he left a way of escape for the gases he also left a way of escape for the steel. Moreover, vessels of extraordinary strength were needed to withstand such a tremendous pressure. However, he persevered, and finally achieved his object. He made his vessels with a porous lining, so that, when he exerted pressure upon the steel, the gases could escape by way of the lining. The metal produced by this process was called compressed steel, and was very much stronger, as well as much easier to work than any other kind.

The history of the automobile would be much longer if our grandmotherly Parliament had not nipped it in the bud by vexatious legislation. As we have seen in Chapter IV, the engines of Cugnot, Murdoch, and Trevithick were the first road automobiles, and in the years following their experiments vehicles of this description were the subject of many trials in Great Britain. Steam-coaches, built by a man named Gurney, plied regularly between Gloucester and Cheltenham in the year 1831. In the same year an experimenter named Ogle produced a carriage propelled by steam, which carried sixteen passengers at the rate of thirty miles an hour, while in 1836 Hancock's steam omnibuses were a feature of London traffic. But the public was not prepared for such an innovation, and the Locomotive Act, passed in 1861, chiefly by the exertions of those interested in roads and railways, forbade the use of automobiles upon roads except within very narrow limits. This act was repealed in 1896, Serpollet's cars having been running in France for five years, and from that date the motor-car has been a factor of increasing importance both in the social and commercial worlds.

The first internal-combustion engine was a gas-engine made by Nicholas Otto, of Cologne, in 1876. It is true that a gas-engine had been designed nearly a hundred years before by Robert Street, but no practical use could be made of it. Even Otto's gas-engine was clumsy and unreliable, and it was many years before serviceable engines of that particular type

were evolved from his invention. But working with Otto was a man of middle age who was clear-sighted enough to grasp the possibilities of an internal-combustion engine. This man was Gottlieb Daimler, who, although he is nothing more than a name to the majority of his followers, was the pioneer of motoring.

Otto's engine was slow, and at its highest speed made only 250 revolutions a minute. Daimler proposed to quicken its working powers, but he was told that such a course was impossible, since the engine would overheat, and, not being able to maintain its position, would overturn and run itself to death. He had, in fact, to tread the dreary path that most inventors have to tread, and like them, to tread it alone. Nevertheless he was not daunted. After repeated attempts he built an engine which, without any of the disasters predicted for it, attained four times the speed of Otto's. In the year 1886, with fear and trembling, he applied this engine to a bicycle, but the results fully justified his expectations. For three years he rode his motor-bicycle, for which he felt all the pride and affection of a father, having also, in 1887, successfully fitted a similar engine in a boat. The following year he completed his second engine, which ran with greater smoothness than his first, but produced twice as much power.

At that time the firm of Panhard & Levassor had a flourishing business as makers of wood-working machinery. They were progressive people, but it is

hard to think that even in their wildest flights of imagination they had pictured themselves as makers of horseless carriages. However that may be, Levassor heard of Daimler's engine, saw it, examined it, was conquered by it. His firm secured from Daimler the French patents of the engine, and began the manufacture of motor-cars. The new vehicle did not immediately come into favour, for the early specimens were anything but trustworthy, but in 1894 the *Petit Journal* organized a trial run from Paris to Rouen. The results were unexpectedly good, and proved decisively that the motor was something better than a tiresome and costly craze. The trial was succeeded by others, and then by a series of trans-Continental races, which spurred both makers and drivers to exert their utmost efforts. Consequently materials and efficiency reached a high standard, and the public was shown that the best makes of automobiles were reliable and useful.

As usual, Great Britain was backward in adopting the new idea, and by this reason was spared the expense and delay of initial mistakes. Moreover, British engineers started upon automobile construction with a very thorough knowledge of the properties of steel and its alloys. In this way they were soon able to improve upon the methods of French builders, and by using the best possible materials for every purpose they soon reduced the weight of the cars they built while increasing their efficiency. For ordinary purposes British-built cars to-day are the

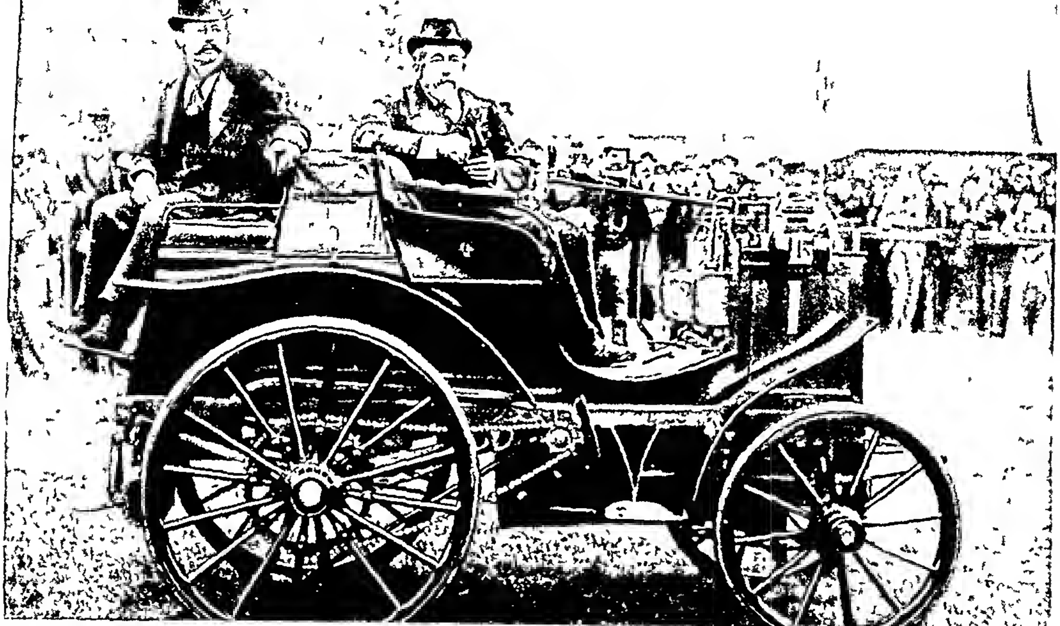

Photo Russell

ONE OF THE FIRST PETROL-DRIVEN ROAD VEHICLES

The Hon E. Ellis, the first owner and driver of a motor car in this country, is seated in front

Chap II

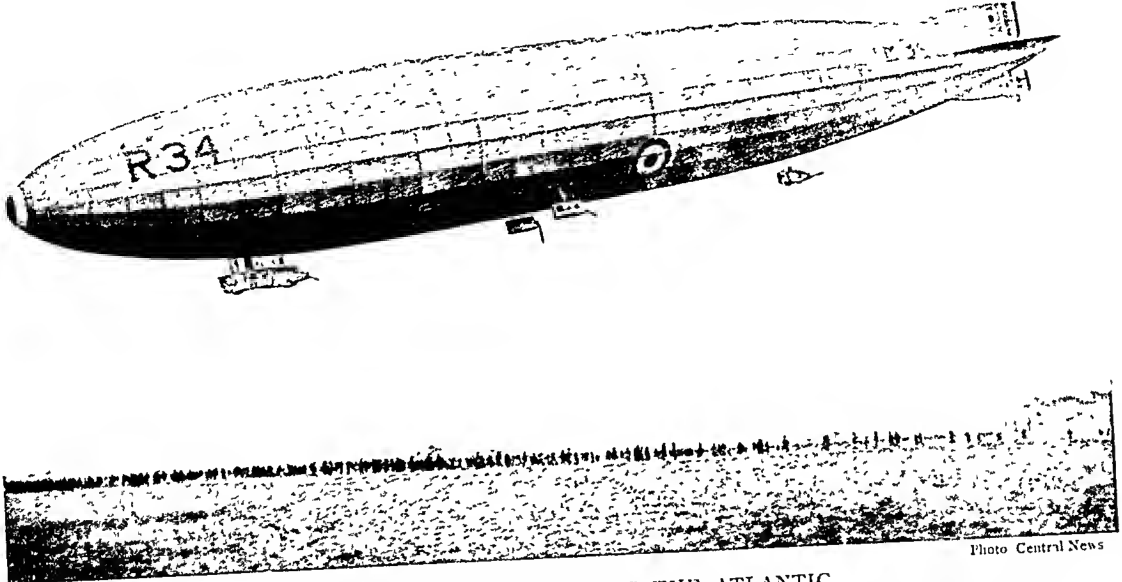

Photo Central News

THE FIRST AIR-SHIP TO CROSS THE ATLANTIC

The air ship R 34 crossed from East Fortune, in Scotland, to New York in 108 hours, and made the return journey in 75 hours. She was 643 ft. long, with a maximum diameter of 78 ft 9 in. The linen covered framework enclosed 19 drum-shaped gas bags containing nearly 2,000,000 cu. ft of hydrogen gas. Inside the hull was the keel, forming a tunnel through the air chambers. It gave access from one gondola to another, and contained the combined dining and recreation room of the crew. The wireless installation had a range of 1000 miles.

Chap VI

very best obtainable, their only rivals being the highest class of French automobiles.

The most modern addition to the world's equipment for speed is, of course, the aeroplane. For centuries men dreamed of flying—sang songs and wrote poems about flight, and devoted years to trying to solve the problem. They only dreamed of flying by the help of wings, of which their own arms should supply the motive power. They never succeeded, for, as we know now, they were working upon wrong lines. In view of the achievements of the last century, it is unwise to denounce any project as impossible, and the day may yet come when men will fly by means of wings, bird fashion, but up to the present *such a mode of progression has not matured. Man's* backwardness in learning to fly has been chiefly caused by lack of means and material. While the power of steam was known and appreciated, petrol and the internal-combustion engine were unheard-of until recent years. The world's oil-wells had not been touched, and the distilling of an explosive spirit from them never thought of. Metal work of all kinds was heavy and unwieldy, for steel and aluminium were not upon the metal-worker's list of commodities. Last, but by no means least, the suspicion and superstition with which every attempt at progress was regarded were effectual in preventing systematic experiment by men advanced in any branch of thought.

One of the earliest experimenters in the problems of flight was Leonardo da Vinci, a genius who distin-

guished himself in more ways than one. He did not succeed as an aviator, because, like all the first men who wished to fly, he thought that the proper way of doing so was by means of wings. He designed an elaborate apparatus which was to enable him to imitate the birds, and actually constructed several models; but he never learnt the secret of flight. Through the centuries which have slipped by since his death many other brave spirits have followed his example, and have tried to lift themselves from the ground by wings of different shapes, but without succcss.

Now we have to make a big jump—from the fifteenth century to the nineteenth—before we find any real development in the science of aviation. No one in the meantime had made any progress, for the simple reason that no one had grasped the physical laws which govern flight. About the middle of the nineteenth century, however, an experimenter named Wenham made important discoveries with regard to the flight of birds, drawing the conclusion that a wing surface large enough to lift the weight of a man would be too large to manipulate. He therefore suggested the use of several small surfaces arranged in tiers. The machine which he constructed upon this plan never enabled him to fly, but it taught him a great deal; in fact, it established his theories regarding flight. These theories were brought before the world in a book written by von Helmholtz. Helmholtz was able, by his own scientific knowledge and the results of Wenham's experiments, to prove indisputably that

men who were devoting their energies to the design and manufacture of wings were wasting their time. Salutary though this advice was, its most noticeable effect was that of diverting the ardour of would-be aviators from wings to balloons.

The serious sport of ballooning had received much attention since its invention by the Montgolfiers. Joseph and Etienne Montgolfier, being of an ingenious and enquiring turn of mind, discovered by a series of experiments that small spheres, when filled with hot air, would rise upwards and float away. Not content with making small balls, they next began to make big ones, and the first public demonstration of the buoyant properties of hot air was made with a ball thirty-five feet in diameter. The ball was made of varnished silk and filled with air heated by a large fire. It speedily rose to a height of nearly two thousand yards, and the good people of Annonay who had assembled to see the sight were hugely pleased. This display took place on 5th June, 1783, and was followed by others which were witnessed by the king and the aristocracy. So successful were all these trials that, after safe journeys had been made in a crate attached to a balloon by a sheep and some poultry, it was decided that a trip should be made by human passengers. Such a trip would by no means be free from danger, for in order to maintain the buoyancy of the ball it was necessary to have a fire burning in the cage. Nevertheless a volunteer was found who was only too anxious to have the glory of

time was proved to the whole world. Other nations soon established balloon corps with admirable results. The work of British balloonists in the South African War, and the formation of the Aero Club in the United Kingdom in 1901, stimulated an interest in the sport which waxed stronger and stronger until the arrival of the aeroplane.

By virtue of its mechanism alone the aeroplane would naturally attract many more enthusiasts than the balloon. Young men born twenty or twenty-five years ago, growing up with the petrol motor and spending callow hobbledehoy years in its company—that period when the novelty of the motor had passed and its defects became horribly apparent—have a genuine affection for the machine as well as a thorough working knowledge of its mechanism. Such young men pass by natural processes beneath the spell of the aeroplane, which provides them with more than a spice of danger and supreme adventure. But they never would have made balloonists.

Experiments with dirigible balloons attracted a great many followers, since a balloon which was entirely at the mercy of the winds was obviously of little use except as a scientific toy. But for many years the attempts to provide balloons with mechanical driving and steering power were unsuccessful. The Robert brothers, whom we have met already, built a balloon in 1784 which they propelled by means of oars. On several occasions they made short trips in calm weather which, to a certain extent, fulfilled their

expectations, but no reliance could be placed in the machine. Other attempts followed, none of them achieving any measure of success until 1852, when a Frenchman named Henry Giffard constructed a balloon which was capable of being steered slightly out of the direction of the wind. This machine was provided with winged propellers driven by a steam-engine, and was the first aerial craft to be so driven. In the early 'eighties Renard and Krebs made an airship which in shape was the forerunner of the "Zepps" of to-day. The balloon was cigar-like in shape, and a hundred and sixty feet in length. By means of a screw propeller driven by electricity she managed to travel at a speed of seven and a half miles an hour. The airships which achieved such startling successes in 1898 were of this same cigar-like form, and it is safe to say that this shape has now been definitely adopted for the airship. It was in 1898 that Santos-Dumont won the Deutsch prize of £4000, and in the same year the Zeppelin first obtained public notice.

Imaginative books, written before the outbreak of the Great War, always laid special stress upon the devastation which would be wrought by dirigible balloons or airships in time of war. Whole cities, we were told, would be reduced to mere heaps of smoking ruins; an entire country would be panic-stricken, and peace would be sought upon any terms. But another point of view was very strongly held at the time, when Zeppelins and similar types of aircraft

were still in the experimental stage. This was the opinion that by their very nature airships could never become of practical use either as a military arm or a means of peaceful locomotion.

So great an authority as Sir Hiram Maxim adhered strongly to the latter theory. In the *Times* of 26th February, 1908, he expressed his views in a letter, from which the following extract is taken:—

"Take that triumph of engineering skill, the 'Nulli Secundus'. The gas-bag, which was sausage-shaped and twenty-five feet in diameter, was a beautiful piece of workmanship, the whole thing being built up of gold-beater's skin. The cost of this wonderful gas-bag must have been enormous. The whole construction, including the car, the system of suspension, the engine and propellers, had been well thought out, and the work beautifully executed; still, under these most favourable conditions, only a slight shower of rain was sufficient to neutralize its lifting effect completely—that is, the gas-bag and the cordage about this so-called airship absorbed about four hundred pounds of water, and this was found to be more than sufficient to neutralize completely the lifting effect. A slight squall which followed entirely wrecked the whole thing, and it was ignominiously carried back to the point of departure."

The principal arguments against the dirigible balloon were these: the enormous horse-power required to drive the propeller, the impossibility of making a lighter-than-air machine capable of really

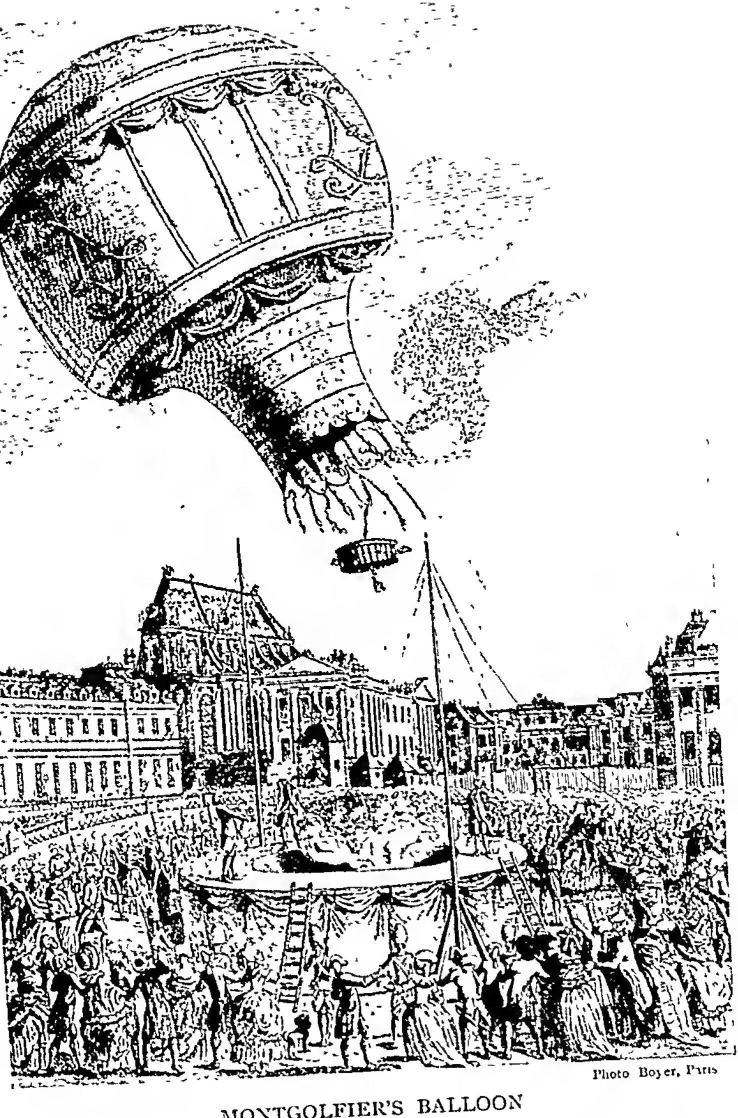

Photo Boyer, Paris

MONTGOLFIER'S BALLOON

The ascent at Versailles, September 19, 1783 From an engraving in the Bibliothèque Nationale, Paris

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resisting the wind, the difficulty of controlling the hydrogen gas with which the gas-bag must be filled, and of maintaining inflation of the bag in spite of the inevitable leakage of hydrogen.

There is now no doubt whatever that the airship will become a practical commercial proposition. To this end not the least important contribution is the achievement of a British firm in extracting the rare gas helium from the air. Hydrogen has many disadvantages, not the least being its inflammable nature, and helium, which will not support combustion, appears to be the one possible non-flammable substitute for the inflation of dirigibles. It is, however, exceedingly rare, the only considerable supply of it coming from the United States, where it is produced from natural gas. Experts consider that the success, in 1925, of the British Oxygen Company in obtaining helium from the atmosphere is of the greatest promise for airship development.

Count Zeppelin—"Papa Zeppelin" as the German children sing of him—did not begin the work which has made him famous until he had officially retired into private life. He was born in 1838, and adopted the military profession as a matter of course, winning distinction during the Franco-Prussian war. When the time came for him to withdraw from active service he devoted his leisure to the problems of aeronautics, being determined, if he could not serve his country as a soldier, to serve her as an inventor. Needless to say, no one in authority gave an instant's attention to

his ideas. It was considered laughable that a worn-out old soldier should attempt to solve so difficult a riddle. But, poor and friendless though he was, Zeppelin did not mean to be beaten. He was fortunate in this, that he knew what he wanted to do, and he knew what means he could use to achieve his end. The old-fashioned spherical balloon had to be remodelled to provide it with rigidity and resistance to wind and weather. The motive power to be used had been invented already, and Zeppelin had long been familiar with it, for he had received most of his education at Stuttgart, where were the works of Otto Daimler.

Daimler's internal-combustion engine was to drive the airships of the future, but the first problem was to make a gas-bag large enough to lift an engine strong enough to drive it. What shape had it to be, and what material could be used? Strength without weight was the constructor's motto, but how could he follow it? The shape he could only decide by actual experiment founded on his scientific knowledge, but the selection of material was a simpler matter, for metallurgists had made the way easy for him there. Without aluminium we should never have had airships, but with aluminium—the metal that is strong as well as light—even flight becomes possible.

From the beginning Zeppelin realized that the cost of his experiments would necessarily be very high, and that he would have to bear it all himself. His pension was small and would not provide more than

a fraction of the amount he was bound to expend, so he sold all his property, realizing from every source a sum equal to about £30,000. With this he started to build his first airship. First, he had to devote a long period to purely experimental work to enable him to decide the form and design most suitable for his purpose. Then he began seriously to construct Zeppelin I. It was a crooked task. Difficulties appeared at every turn; difficulties with work-people, difficulties with materials, heart-breaking delays, bitter opposition. At last, however, after two years continuous work, Zeppelin I made her first ascent on 17th October, 1900. She flew for a short distance over Lake Constance and came safely to earth again, thus achieving a certain amount of success. But her second trip was disastrous, and she was utterly wrecked.

Without wasting time on vain regrets, Zeppelin started to make a second airship. Unfortunately his resources were not as elastic as his temperament, and before long ruin stared him in the face. The authorities would do nothing to help him, but a few personal friends came to the rescue, and with their help Zeppelin II was finished. This machine proved entirely practical, and behaved so well that the attention of the Government was aroused.

Since those days, the construction of airships has passed out of the experimental stage, although much still remains to be done before we can claim to have reached perfect reliability under all weather conditions.

No monster of the air imagined by Jules Verne was quite so marvellous as the latest type of airship, hailed as it is by the press as "super-giant". What uncouth compound will be coined to greet later developments in airship construction, when still "superer" giants will dwarf all previous achievements? The air-liner known as R 101 is to have a gross lift of 155 tons, raised by 5,000,000 cubic feet of gas, and will be capable of a speed of from 70 to 80 miles an hour. Another type of airship, under construction by Commander Burney and Mr. B. M. Wallis, is expected to reach a speed of 90 miles an hour, owing to the "stream-lines" of its design. These improvements in design, consisting mainly in the arrangement of the cars, which are drawn up into the hull of the ship instead of impeding flight by being suspended, have been made possible by a new type of mooring-mast. Mooring-masts of this pattern are to be erected at various stages of the world's air-routes, and it has been tentatively accepted as the standard type by the international experts who are engaged in mapping out lines of air-travel. This Burney-Wallis mast has at its summit two platforms which project at right angles, and for mooring purposes the airship can be brought between them. The non-stop flight of such a ship, carrying its maximum load, is expected to be 3500 miles. That conveys more to us when we look upon it as the distance between London and Baghdad—the city which seemed as remote as the moon when we read the *Arabian*

Nights, but is now a mere two days' journey from London. Australia will soon be no distant continent, but another island which we visit at the cost of ten days' travel, while the flight to India will occupy little more than a week-end.

In addition to the stationary mooring-masts on land, it is proposed to have special masts erected on naval monitors or other suitable ships, to enable airships to re-fuel at sea if necessary.

The air-liner of to-morrow will be as luxuriously equipped as the Atlantic liner of to-day. All the ease and elegance which the modern traveller demands will be there, and no inducement to kill time will be absent. Doctors will recommend air-voyages where formerly they advised sea-voyages, and one can hardly imagine any treatment more stimulating than that of travel through the upper air, crystal clear and pure as the sky itself.

The airship is, of course, a direct descendant of the spherical balloon, but the aeroplane is a new and original device, which must be credited entirely to the twentieth century. The immediate predecessors of the aeroplane were the kites and gliders, to which many inventors devoted years of serious work. The chief value of these instruments lay in the lessons they taught. By their use much was learnt concerning wind pressure and resistance. Wilbur and Orville Wright, pioneers whose courage was only equalled by their perseverance, began their experiments in flying with gliders. These machines were made on

the biplane principle, that is to say, they consisted of two planes, placed one above the other, and connected by a light framework. In gliding, a start has to be obtained from the summit of a hill, yet high or gusty winds seriously interfere with the machine. The Wrights found an eminently suitable spot for their enterprise on the coast of Ohio, where the wind blows steadily but not too strongly from one direction during the greater part of the year. Here they worked assiduously to conquer the main difficulties of the problem they had set themselves. At that time, the very earliest days of the present century, so little was definitely known of the possibilities of flight that the best position for the passenger had not been decided. Some experts adopted a recumbent position, facing downwards, while others stood upright. The Wrights tried both ways, and ultimately decided in favour of lying down. They also had to learn the effect of a rudder, and after many trials, found that a rudder at the back of the machine performed the operation of steering to right or left with most success, while a rudder in front would direct the flight upwards or downwards, the rudder at the back being in a vertical position, while that in the front was horizontal. So marked was their progress, that in 1903 they had learnt enough of stability to attach a small motor to their glider. During the year 1903 the longest distance the glider covered through the air was three hundred yards. In 1905, in their motor-driven machine, they flew twenty-four miles.

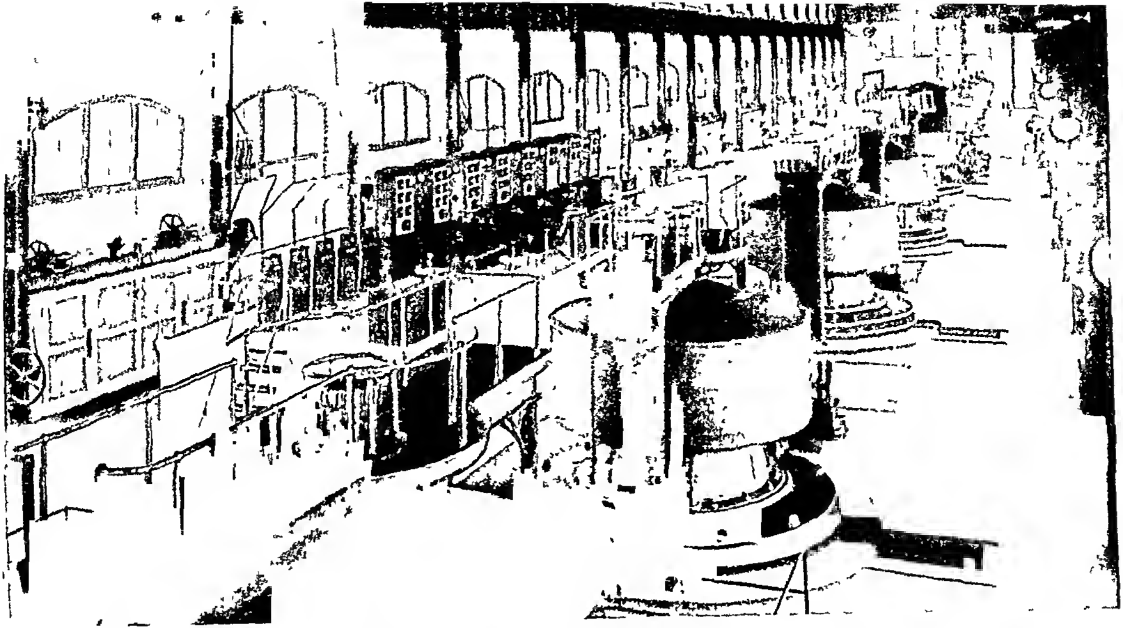
Since those days a great industry has arisen in the construction of aeroplanes and seaplanes, and a great new profession calling for more skill, pluck, and endurance even than either of the services it touches.

One of the most startling incidents of the year 1924 was the unexpected success of the autogyro or "windmill" plane invented by Señor de la Cierva, and exhibited at Farnborough. This machine responded admirably to the exhaustive tests imposed upon it, in particular proving its complete ability to hover in the air at a standstill for as long as required or to alight flying vertically. Several machines of this type are being built for the Royal Air Force in order to give them a thorough trial as practical machines. Experimental machines of very high speed are also to be added to the equipment of the R.A.F.

A very important addition to aeronautical work has just been made by M. Louis Damblanc, a French air engineer, in the shape of a device for adapting the air-intake of a motor to atmospheric pressure at any height. Like its pilot, the aero engine finds the rarefied atmosphere of the upper air very trying, and this new invention, the details of which are still secret, will enable aviators to reach in safety even an altitude of 8 miles. Needless to say, the pilot is also provided with an apparatus to ease his breathing.

A great deal of attention has recently been devoted to parachutes, to provide a way of escape for the occupants of air-craft in case of disaster. One such parachute was recently used in America with complete

success, but it cannot be denied that as much credit should be given to the pilot using it as to the parachute itself. A certain kind of aeroplane wing had been causing great trouble to the United States Air Service by its tendency to collapse when diving at a high speed. With the object of discovering the reason for this weakness, a certain pilot, from whose composition the constituent of fear must be entirely absent, took a machine provided with this type of wing to a great height and then dived. While the earth was rushing towards him with appalling speed he coolly made his observations, noticing that the disturbance began at the extreme tip of the balancing planes, the tremor passing on to the wings themselves, which caused the main planes to buckle and break up—and then he jumped, landing safely by means of the parachute, while the aeroplane crashed to the ground an utter wreck.



THE WORLD'S GREATEST WATERFALL HARNESSED TO SUPPLY ELECTRICITY

The picture shows the vast electric plant in Power House No 1 of the Niagara Falls Power Company's Station. The water is led through tunnels to turbines which drive the electric generators

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CHAPTER VII

Power

When the world was very young—so young that men were but children—there were legions of giants and genies ready, so the fables say, to do any difficult task that was required of them. Nowadays, when we have some big and difficult task before us we no longer call up a magician by rubbing a ring, for we have three powerful servants who will work for us for the asking. Merely the pressing of a button, or the turning of a handle, or the opening of a valve is required to set these mighty forces to work.

Wonderful though the steam-engine is, it is overshadowed by its younger brother in servitude—Electricity. (The stationary steam-engine, puffing and snorting away in a corner or basement of some big factory, performs marvels of industry in every part of the building by means of elaborate systems of belts, pulleys, and shafts, which carry the movement of the piston, and adapt it for working individual machines. But all this mechanism, coming between the source of power and the application of it, necessitates great loss of energy.) It is usually estimated that half the horse-power produced by a steam-engine is lost in

working the intermediate machinery. This is obviously a colossal waste, but one which up to the present has been regarded as inseparable from the use of steam. Here it is that electricity shows us a better way.

Electrical power can be transmitted very simply and economically—in this lies the point of its superiority over steam. One dynamo working smoothly and quietly can supply current to be carried by hundreds of wires, not only to all parts of a building but to all parts of a town. There is no necessity for the dynamo itself to be on the spot. It may be many miles from the place where the current is required, yet the loss of power during transmission is relatively slight. Thus it is possible for natural sources of power to be made to perform all kinds of work at some far-distant point. A stream of water falling down a mountain-side in a remote corner of Wales might generate electricity for use in a town in Norfolk, while a "force" in Westmorland might run trams in Oxfordshire. Even in Great Britain, which is a country deficient in water-power, much might be done by the energy of rivers, but when we enter lands of high hills and lusty streams we realize what can be accomplished by modern descendants of one of our oldest forms of power—the Water Wheel.

The Pelton Wheel, a brother of the Steam Turbine, is simply a development of the old slow-moving wheel so rarely seen to-day. The old-fashioned mill built by the side of some meandering river, with its weir and

mill-race, is still a feature of the landscape, and little more, in country places. The water falls pleasantly upon the vanes of the wheel, not too fast, and in dry weather not quite fast enough. But the wheel generally turns with sufficient force to turn the shaft which turns the ratchet which turns the stones, and in the words of the old song relating to the Jolly Miller, "As the wheel went round he made his fill". A gentle, leisured existence, not without its charm in these days of ceaseless activity, of day shifts and night shifts, of striving after efficiency and economy to the invariable accompaniment of the cry of "Speed up!" The miller of yesterday would find it hard to be taken suddenly from his peaceful English home, with its surrounding water-meadows lush in summer with rushes and yellow flags, and be put in charge of a water-mill of to-day.

He would find himself, let us suppose, in California, or Norway, or Switzerland, or in any part of the civilized world where man has made some of the torrent work for him. Instead of the gentle splash of his mill-wheel our jolly miller would hear a vast all-pervading roar day and night. Whatever noise may be made by the machine which has been placed beneath it is utterly drowned by the noise of the fall. The inexperienced might well be forgiven for thinking that the force of the fall, however controlled and directed, would be so great as to forbid its being utilized. But modern inventors, fortunately for the world, refuse to admit the existence of such a word

as impossible, and the waterfall, least tractable of the mobile giants of nature, has been persuaded to spare some of its strength for the gigantic schemes of civilization.

There are many of these amazing enterprises in good working order at the present time. The wondrously beautiful Snoqualime Falls, in Washington State, provide electricity for the towns of Seattle and Tacoma, eighty-three miles away, and that is among the least of the long-distance transmission services which the water turbine has called into being. Some services are transmitted as great a distance as two hundred miles; in fact, all conditions being favourable, there seems to be a very remote limit to the distance over which current might be carried. But conditions are not favourable, and the maintenance of an electricity service which is brought from a long distance is fraught with many dangers and difficulties, and can only be achieved by the exercise of ceaseless vigilance.

It is by no means necessary, however, for water to plunge violently over a steep place before it can be used to generate electricity. It may be piped where it springs from the mountain top and carried down in pipes to the place where it is to work, but piping is expensive and could be used only for comparatively short distances. It is naturally a great deal simpler to transmit an electric current through a wire than a volume of water through pipes.

Another of man's very early friends now helps him

by generating electricity. Windmills have been used for grinding corn and similar operations for a long time. We no longer use them to any extent for that purpose, but we erect wind-vanes for working dynamos.

Wind-power has the obvious advantage of cheapness, and in many countries it is fairly constant. The old constructors of windmills knew all about the importance of catching the breeze, and they built their mills with movable head-pieces so that the sails could be turned as the wind shifted. Now we do better than that. We erect a tower of open steel lattice, instead of round stone or brick houses, and at the top of this tower we place a wheel composed of movable vanes. These vanes automatically turn as the wheel revolves, just as a skilful oarsman feathers his oars. Plenty of space is left between the vanes in order to allow the wind to pass freely between them. The shape of the sails also has to be considered very carefully. Curved sails have been proved to give results that are nearly twice as good as straight ones, but curved wings present certain difficulties. These difficulties are avoided by the use of deeply-grooved flat wings, and by increasing the size of the wings proportionately more power is obtained.

The Danish Government has been to the fore in encouraging the construction of wind-engines, and it has been fortunate in having two men of great ability to carry out experiments in this branch of mechanical science. Professor La Cour may be said to have

made the first steps towards the development of the new power, and Soerensen, the brilliant young Dane, amplified and improved upon the ideas of La Cour by introducing the curved sails.

These wind-motors must be built with a view to the locality in which they are to work. Where the prevailing winds are light it is necessary to allow the escape of excess of energy. In Continental countries, for instance, the windmills may have to be regulated for a breeze of six or eight miles an hour, and any power very much in excess of that has to be allowed to waste. But in any situation where the prevailing winds are strong the vanes are able to utilize all the power they can catch.

There still remains much to be done before the wind-engine can take a high place amongst the prime movers of the world, but its many advantages are obvious. It is operated by natural power, and makes no claim upon our fuel reserves. It is cheap to run, and the first cost is comparatively low. Better still, it is pre-eminently a power for the countryside, where winds blow strong and free without suffering any check from high buildings and chimney-stacks. By the erection of windmills many industries might be carried on profitably in rural districts, while the ordinary tasks of the farmer could be immensely lightened by a small wind-driven engine.

Thus have water and wind, our two natural servants, been modernized and entered for competition with newer forces. At present they have not reached

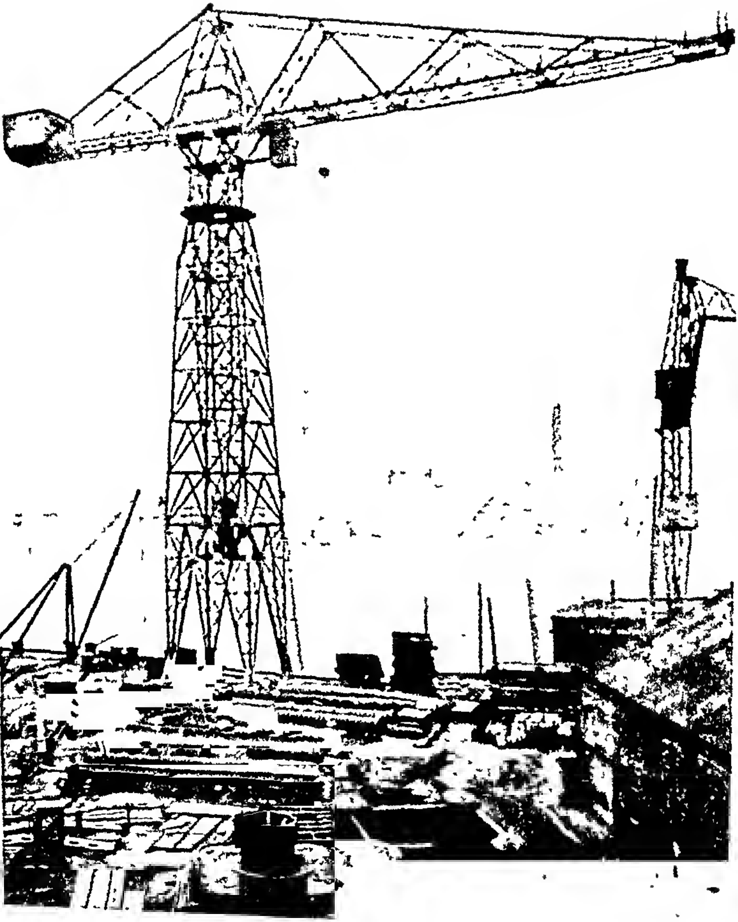
their highest efficiency, but in days soon to come our inventors must give serious attention to the perfecting of wind and water motors, two forms of prime movers which make no demands upon coal or oil. Before, however, we can obtain electricity as plentifully as we should by the agency of wind and water, plant and storage both must be reduced in cost and brought within the reach of small capitalists. Although on the whole Great Britain, and England in particular, is deficient in rapid rivers, there are few farms which are not served by streams strong enough to run an electric-lighting plant, and, as a matter of fact, what we lack in streams we make up in steady breezes, which can keep windmills twirling merrily eleven months out of the twelve. If every large farm and country estate were lighted and heated by naturally-generated electricity, what a great saving there would be in the nation's coal and oil bills!

Gas, the third and in many respects the most modern of our three servants, is a more highly complicated subject than either Steam or Electricity. After all there is but one kind of steam and one kind of electricity, however differently they may be controlled and applied. But there are many different kinds of gas. There is the ordinary everyday coal-gas, which we burn in our houses for the simplification of domestic tasks. There is water- or producer-gas. There is the gas generated in the explosions of the internal-combustion engine, and there are the gases generated by any of the high explosives.

Gunpowder is the oldest of our explosive substances; the gas consequent upon an explosion of gunpowder is the oldest instance of gas in servitude.

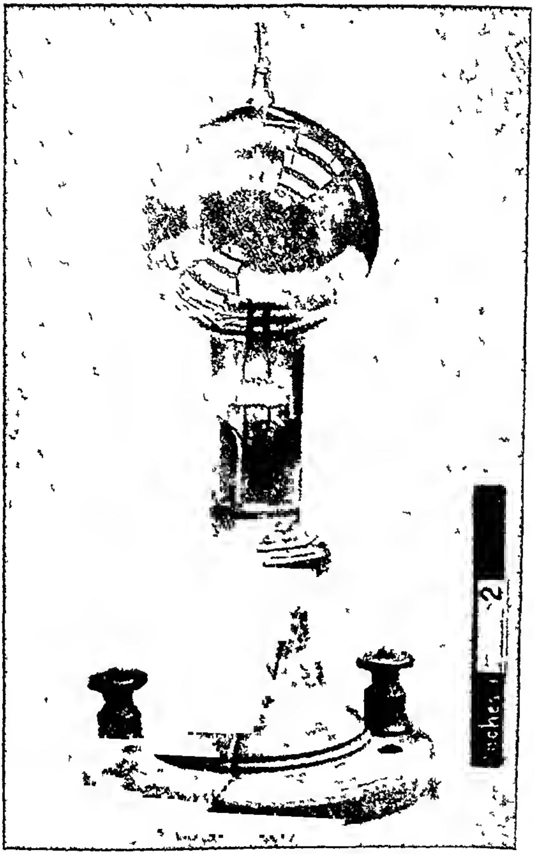
The Arabs used gunpowder in very early times, but it was not known in England until the master-mind of Roger Bacon introduced it in the year 1270. Then for centuries the improvement in the methods of handling gunpowder was negligible. There were, of course, improvements in cannon and gun-making, and the noble art of war advanced considerably—if increased dexterity in slaughtering one's fellow-creatures can be described as a forward movement. But the beneficent uses of gunpowder were not understood for a very long time. Mining, road-making, building, and agriculture, all were carried on by manual labour alone. It was not until the early years of the seventeenth century that there is any recorded instance of the use of gunpowder in mining operations. This advance was due to the ingenuity of some German miners, and it was by German miners that blasting was introduced into England many years later.

So long as blasting was necessary only to miners, there was little progress made in the method of conducting the operation. But when the railway era dawned, and the whole of the civilized world was seized with a desire to dig and delve, the question of blasting and blasting-powders acquired a new importance. How can we accelerate cutting? asked the engineers. How can we make our railroads direct



AN ELECTRIC TOWER CRANE ON THE CLYDE

This huge machine, which is 110 ft. high, has a radius of 100 ft., and is controlled and worked by electricity. A magnet is sometimes fitted, by which the object to be moved is held by magnetic attraction. *Chap. VIII*



EDISON'S ORIGINAL INCANDESCENT ELECTRIC LAMP

This is an early experimental lamp of Mr Edison The filament, which is of carbonized cane fibre, has fallen into the neck of the globe The lamp which is now in the Science Museum, South Kensington, London, gave a light of 13 candles with a life of 1390 hours

without burdening them with prohibitive gradients? How are we to build our railways in rocky lands? At first gunpowder supplied the only answer to these questions, but gunpowder would not do all that was required. Something much more powerful was wanted. Then began the wonderful series of experiments which has given to the world all the powerful explosives of modern times.

As you know, gunpowder is composed of charcoal, saltpetre, and sulphur, and up till the 'thirties that remained the only explosive in general use. The extraordinary effects of nitric acid upon certain substances was discovered in 1832 by a French chemist named Braconnet. Following upon this came the invention—if such it can be called—of nitro-glycerine in 1846, by Sobrero, an Italian chemist. Nitro-glycerine is a mixture of nitric and sulphuric acids in which glycerine has been dissolved. Sobrero, however, regarded his new explosive simply as a curiosity, and did not attempt to use it commercially. It is very strange to think that the man who gave to the world some of its most deadly substances should be he whose name is associated with an annual Peace Prize. It was Alfred Nobel, a Swedish engineer, who saw the value of Sobrero's discovery, and devoted his energies to making it a thing of world-wide importance.

Nobel spent his early manhood in his father's factory making torpedoes and explosives. Thus he prepared the way, all unconsciously, for the great work

of his life, and ultimately found in Sobrero's discovery the basis of the explosive substance which all the world was waiting for. Nitro-glycerine by itself was too dangerous a substance to be handled and carried about to be desirable as an article of commerce. It was of great value as a blasting agent, but too liable to explode at the wrong time, in spite of all precautions which forethought could devise and vigilance enforce. Nobel found that by mixing the nitro-glycerine with an absorbent substance it retained all its efficiency while losing much of its terror. The difficulty was to hit upon just the right absorbent substance. Many things were tried during the experimental stages—sawdust, rags, paper, charcoal—anything, in fact, which seemed to have powers of absorption, but none of them gave really satisfactory results. But the world is large and contains an infinite variety of material, and so, at last, the proper one came to light.

The story of the Flood is not a myth. Not one flood, but many, submerged the world from time to time. This being the case large deposits of the remains of marine animals and plants are found in different places, each having its own special properties. One form of such deposits is known as *kieselguhr*. It is found in Scotland, Germany, and Norway, and more rarely in other parts of the world. It is composed of the siliceous remains of algæ which flourished an unthinkable number of years ago. The living part died, but the tube-shaped stem, a skeleton of silica, still exists in its original shape. These remains

of countless billions of living creatures, compressed by ages of geological activity, form a light porous earth which proved to be the ideal substance for Nobel's purpose. When the *kieselguhr* has been calcined, ground, and sifted it is practically pure silica.

The making of dynamite is naturally a delicate and dangerous business. The greatest caution has to be exercised, the most important factor being the preservation of a low temperature. In these days accidents are happily rare, but when disasters do occur they are apt to be wholesale in their destruction. Yet the uses of dynamite are as much beneficent as otherwise. It is unsuitable for quarrying, being too violent in its action, but for mining purposes it is of great value. It opens up new countries in a marvellous manner, preparing the way for canals and railways. It will remove huge rocks from a settler's field, or gently stimulate the bacteria in his soil and cause exuberant crops to spring up. Nobel may not have foreseen this last-named application of his wonderful invention, but if he had it surely would have rejoiced his heart.

In spite of all the achievements of our heaven-sent inventors it is foolish to suppose we are nearly at the end of our resources. We have, in fact, still two reserves of appalling and limitless power as yet untouched. No man, as yet, has harnessed the sea. Day and night, year in and year out, that mysterious force we call tide is ebbing and flowing with monstrous regularity quite outside our control. We can write

a tide-table for any sea-coast spot on the map for a hundred years hence, but we can do nothing whatever to hasten or retard that tide by one second of time. Neither can we, as yet, make it work for us. The waves which thunder on our shores perform their own appointed tasks—whatever they may be in the great scheme of things—but none of them are by man's appointment. Some day will be born the giant mind that can use this force for its own ends.'

And what can we say of him who will harness the sun? The source of all life and light and heat, the source of all power, is as yet unconquered. Day by day it maintains our world in its place in the universe, day by day provides us with things necessary to our existence. We can build our houses to resist the heat or invite it, we clothe ourselves lightly or heavily, we can make the light paint us pictures of living or inanimate things with perfect fidelity—but what else can we do?

Sun-engines, sea-engines—those are our dreams, our hope of the future. When all the coal is burned, when all the oil-wells are exhausted, we shall still have our resource in these.

CHAPTER VIII

Electrical Inventions

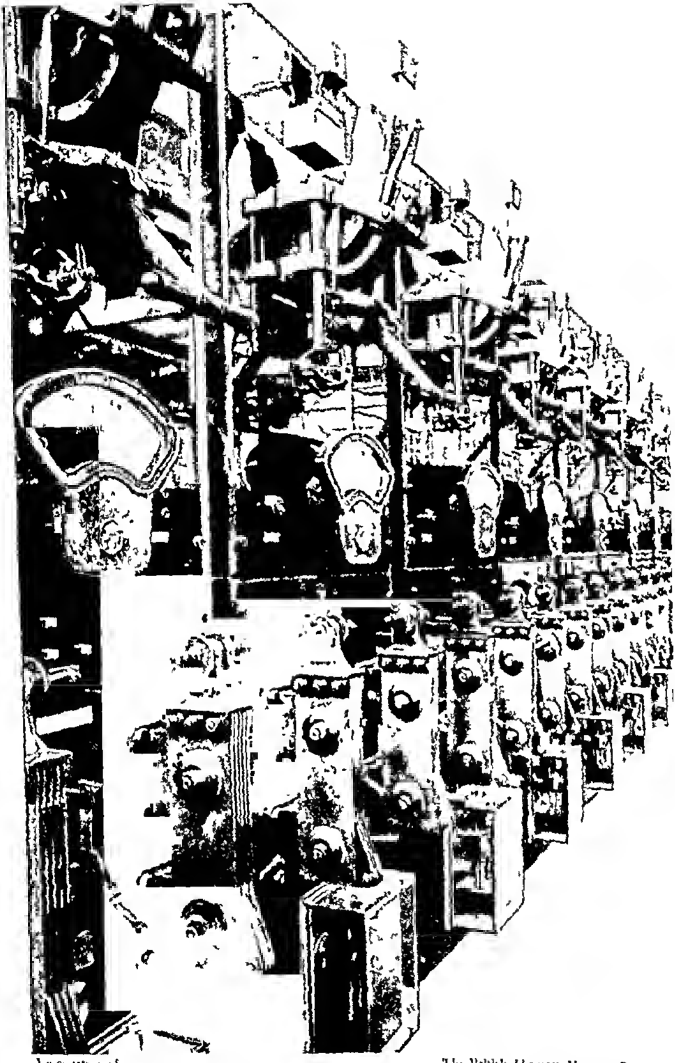
According to Charles Lamb's essay, "A Dissertation upon Roast Pig", a careless boy set fire to his father's house and several little pigs got roasted. The smell seemed delicious to the boy, and when he licked his fingers after touching one of the pigs to make sure it was dead, he found the taste equally delightful. Before this time people had lived on raw meat, but now they knew how much more tasty it became by cooking. At first they used to burn down a house every time they wanted to have roast pork; but soon someone, wiser than the rest, found out how to make and use gridirons, frying-pans, and things of that sort, and so to get cooked food without burning themselves out of house and home. Of course this is only a tale, and not to be taken as real history, but it may help us to understand the difference, or one of the differences, between discovery and invention. Discoveries are sometimes, but by no means always, made by accident. Whether accidental or not, a discovery is a finding out of something that is, in some way or other, already there. The discovery may be of a new island,

a plant, or an animal that no one else has seen or noticed, or it may be of what we call a law of nature. In any case, the discoverer does not make the island or the plant or the law. With invention it is different. Something wants doing that has not been done before, or wants doing in some better way than it has previously been done. The inventor finds how the thing can be done, and very often he does this by contriving some tool or machine specially suited for the purpose. In Lamb's story the improvement in the taste of pig was a discovery, but the making of a gridiron or an oven was an invention. In the progress of a science like electricity, discovery and invention are very much mixed up; each is important, and each helps the other. A discovery is made; this leads to the invention of means for turning it to account, and the inventions lead to further discoveries. Thus, in giving an account of a few of the wonders of electrical invention, we are bound to take into consideration some of the discoveries which have led to them. The very first of these discoveries was made a very long time ago—several hundred years, at least, before Christ. It was found that a piece of amber, that hard, yellow substance sometimes used for making cigarette-holders and the mouthpieces of tobacco-pipes, is able to pick up bits of straw after it has been well rubbed with dry wool. For a long time, nothing seemed to come of this discovery. It was found that jet could be used instead of amber, and there the matter rested century after century. We may well be glad to think that

it was an Englishman who started the ball rolling afresh.

Dr. William Gilbert, born at Colchester in 1540, physician to Queen Elizabeth and James I, took an interest in various things besides medicine, and it was he who found that glass and many other substances shared the properties of amber and jet. He gave to all such substances the name of electrics, from *elektron*, the Greek word for amber. From this also come all such terms as electricity, electrical, electrician, and the like. Other men got interested in the subject, and a number of important discoveries soon followed. For instance, it was found that metals allow electricity to flow over or through them, while dry glass, silk, sealing-wax, &c., do not allow it so to flow. Thus was introduced the important distinction between conductors and insulators. Another discovery was that of the twofold nature of electricity. Whether the two electrical states which are known as positive and negative result from there being two really different sorts of electricity itself, or whether the two states are due to a more and a less of one single kind, is scarcely quite settled even now. There has been a kind of see-saw of opinion on the subject, sometimes one and sometimes the other view being uppermost. In any case there is a very important difference of some kind which the words positive and negative serve to remind us of. Electrical inventions now began to be made; one of the first was the frictional electrical machine. The earliest of these consisted of a large globe of

sulphur, which was rubbed with the hands, and had a metal conductor near it hung up by silk threads. In this conductor electricity accumulated, and sparks could be obtained from it. Improvement followed improvement. Glass was used in place of sulphur, and a cylinder, or later, a plate, was found a more suitable shape than a globe. A special rubber, made of leather stuffed with horsehair and smeared over with a kind of composition, took the place of the human hand. A number of striking experiments can be done with an old-fashioned electrical machine when the weather is quite dry, but it is almost impossible to get it to act when the weather is damp. The place of the frictional machine is now taken by one invented by Wimshurst and named after him. This has two glass plates, which on turning a handle revolve in opposite directions. Each plate has a number of strips of tin-foil or thin brass fastened to it, and there are rake-like pieces of metal known as collecting combs, close to which the plates revolve. Besides these, there are two large brass cylinders supported on ebonite pillars and having a brass knob on each. These are called the prime conductors. The machine works, not by friction, but by a principle called induction. If there is even the smallest electrical charge on one of the slips of tin-foil, and this can easily be imparted, this little charge is multiplied at a rapid rate when the plates are made to revolve. The prime conductors become strongly charged, the one with positive, the other with negative electricity. When



By courtesy of The British Thomson Houston Co. Ltd.

THE SWITCH BOARD THAT REGULATES THE ELECTRIC CURRENT

A front view of a 250 volt heavy current switch board

Chap. XIII

the knobs are placed at a suitable distance apart, greater for large machines than for small ones, showers of sparks pass between them like constant flashes of lightning on a small scale, a strong smell of ozone is perceived, there is a crackling noise like toy thunder to match the toy lightning, and, particularly in a dark room, there are patches of light to be seen almost all over the apparatus. Some of these machines are very large and powerful, and have a dozen or more plates instead of only two. Although the experiments that can be made with an electrical machine are very interesting, and a great help in studying electricity as a science, it is only lately that the machine has been put to much practical use. Quite recently there has been a very great increase in the use of electricity by medical men, some of whom now have a great variety of apparatus for administering it to their patients in all sorts of ways. The Wimshurst machine is considered by some doctors as a very valuable part of their munitions in the war they are always waging against disease. In connection with the Wimshurst and other kinds of electrical machines, the Leyden jar is often used. This is an invention that was suggested by an accidental discovery made by a student of the university of Leyden in 1746. Cuneus, that was the name of the student, wanted to electrify some water. He put it into a wide-mouthed flask and, holding the flask in his hand, let a piece of chain attached to the conductor of the electrical machine then in use dip into the water. When he

thought the water was nicely charged he took hold of the chain to pull it out. The result was a strong shock. Down went the flask, to be broken on the floor, and when he got over the shock he said he would not have another like it, to be made king of France. This accidental discovery got talked about all over Europe, and quite soon the Leyden jar took somewhat the form in which we have it to-day. A glass jar is coated inside and outside with tin-foil to about three-fourths of its height. Through a bung in the mouth of the jar passes a metal rod having a knob at the upper end, and attached below to a chain which rests on the tin-foil at the bottom of the jar. When the knob is connected with the electrical machine and the outer coating is "earthed" by holding it in the hand, a comparatively large quantity of electricity can be stored in the jar. By bringing a bent wire so that one end touches the outer coating and the other is brought close to the knob, a brilliant spark and a loud report are obtained. The separated electricities, positive and negative, rush together and the jar is discharged. Care must be taken by the person doing the experiment, or the electricity may pass through him and give him a nasty shock. The Leyden jar is an example of what are called electrical condensers. There are many kinds of these, different from each other in appearance, but they all, like the original jar, allow a large quantity of electricity to be condensed into a comparatively small piece of apparatus. They are used for many purposes, and in connection with

some of the other electrical inventions to be described in this chapter. A page or so back I compared the noise and light of the electric sparks from a machine to toy thunder and lightning. It was Benjamin Franklin who first definitely proved, what others had suspected, that this was not a fanciful comparison, but that lightning and artificial electric sparks are things of the very same kind, one on a very big scale, the other on a very small one. About the year 1746 Franklin sent up a kite in a thunderstorm. The kite had an iron point, and a key was tied to the end of the string. To the key was fastened a silk ribbon which Franklin held in his hand. The string, wetted by the rain, became a conductor, electricity was able to pass down it from the thunder-cloud to the key, and Franklin could get sparks and charge a Leyden jar by this means. This experiment led to one of the earliest and most useful of all electrical inventions, the lightning-conductor. The sharp point of the conductor stands higher than the highest part of the building, and a path is provided for the lightning through which it may pass harmlessly to the earth if the building should be "struck". This is not, however, the only, nor even the chief object of the invention.

Suppose a cloud, charged to the danger point with positive electricity, is over the conductor. Negative electricity is attracted from the earth and, escaping from the sharp point, partly neutralizes the positive electricity of the cloud. In this way the conductor

often prevents the building being "struck" at all. Just imagine what a great thing it would be if someone could invent an apparatus for protecting our ships against torpedo attacks from enemy submarines which would not only make the torpedo harmless if it did strike the ship, but would also often prevent the enemy from discharging it. The lightning-conductor does for a church as regards lightning what this imaginary invention would do for a ship as regards torpedoes.

If we think of lightning as wild electricity, that which we get by means of electric machines is but half-tamed. Most of the useful work which we make electricity do for us is performed by electric currents, not by the sudden escape of electric charges. Before I say anything of the many inventions in connection with electric currents, it may be well to point out that we never really make any electricity. It is already around us in inexhaustible amount. What we can do is to gather some of it together into an electric charge, or to set it moving as a current. An arrangement for producing such a current was invented in 1800 by an Italian professor named Volta. If a piece of copper and a piece of zinc, each having a wire soldered to it, are put into a glass of weak acid, several things happen. The zinc is gradually dissolved, bubbles of hydrogen gas form on the copper, and a current of positive electricity flows from the copper to the zinc through the wire, and from the zinc to the copper through the liquid. This is the original "cell".

When two or more cells are arranged so as to help each other in sending a current through the same wire, we have a "battery" or "voltaic battery", so named from Volta. Sometimes they are called galvanic batteries. This word is taken from the name of Galvani, another Italian professor, but his share in the invention was very small compared with Volta's. The original cell of Volta had many drawbacks and did not work very well, and a great many others have been invented from time to time. One of the best known of these is the Leclanché, much used for ringing electric bells. Dry cells are somewhat similar to the Leclanché, but contain a paste instead of a liquid. The invention of the voltaic battery was a very important one. It supplied a safe and easy way of getting electric currents, and these currents were, so to speak, quite tame. They could be started and shut off at will, and their habits, like those of other tame creatures, could be thoroughly studied. Ways were found of measuring currents, and great advances were made in the theory of electricity. These battery currents can be used for many of the practically useful purposes which will be mentioned later on. But—and there is an important "but"—the cost of keeping up, for any length of time, currents like those now used for lighting or for electric trams would have been enormous. In nearly all batteries the metal zinc is used—that is, not only employed in constructing the battery at first, but actually used up all the time the current is flowing. The battery is really a kind of engine

in which zinc is the fuel, just as coal is the fuel in a steam-engine. Now zinc as a fuel is very much more expensive than coal. By using up one pound of the zinc, a current of a certain strength can be maintained for a certain time—say an hour; a current of half the strength for two hours, or of double the strength for half an hour. If we take account both of the current strength and the time it flows, there is a limit to what can be done with a given weight of zinc. There are many wonderful things that can be done by the genius and perseverance of inventors, many difficulties that have already been got over, and many others that will, no doubt, be got over in the future. But, on the other hand, there are also impossibilities which can never be got over. Two and two make four, and not five. In a pound of any kind of fuel there is stored up a certain amount of what men of science call energy, the power of doing work. We may waste much of this, and so get less of the kind of work we want out of the fuel; but we cannot get, and never shall be able to get, more work out of our fuel than it contains. So electricity would not be doing for us what it is doing to-day if no other way of setting up electric currents had been discovered besides the use of batteries.

Side by side with the study of electricity had gone on the study of magnetism. The same Dr. Gilbert I spoke of before had paid attention to both, and after his time much was found out about them. The ques-

tion as to whether, and, if so, how, they are connected was often asked, and in 1819 a Dane named Œrsted first got on the track of an answer. He found that if a wire carrying a current passed near a compass-needle balanced on a point, the needle moved, and seemed to try to set itself at right angles to the wire. This discovery led to the invention of various galvanoscopes and galvanometers, instruments for detecting and measuring currents. It was also found that if a long wire, covered with some non-conductor, were wound round and round a hollow tube, then, when a current was sent round the wire, the space inside the tube became magnetic, and a piece of soft iron put into the tube was a magnet as long as the current was flowing. This was the invention of the electro-magnet, and a most important invention it was. It would take up quite a lot of space just to mention the many and various uses to which these magnets can be put. There is a little one in every electric bell. They are used for drawing a bit of steel dust out of a man's eye and for magnetic cranes which will hold up a weight of many tons. Edison invented a magnetic separator for sorting out iron ores. The broken ore has to pass through an apparatus containing electro-magnets. First comes a set of magnets just strong enough to pick out the richest kind of ore, known as magnetite; then a stronger set which separates another kind, containing less iron, called hematite, and the useless residue passes on and is got rid of. Wheat always gets a few nails and other bits of iron

accidentally mixed with it. If these went to the mill with the wheat the grinding machinery would get injured, but by means of electro-magnets every bit of iron is picked out. But something still more important has to be mentioned. Not only can currents be used to make magnets, but magnets can be used to set up currents. There are many ways in which this can be done, but all these ways really depend on the same principle. I will try to explain this as clearly as I can, but it will not be easy. Suppose you have a little compass-needle, that is, a tiny magnet. Mark one of its two ends or poles with a spot of paint, and let the needle be so balanced that it can turn into any position. In an ordinary room or out of doors, here in England, the compass-needle will set itself with one of its poles, which we will suppose to be the one we marked, pointing towards the north, but also dipping downwards very considerably. Touch the needle with your finger so as to move it into some other position. Left to itself it swings about for a while, and then settles down so as to point just as it did at first. We say that the needle is acted on by the earth's magnetic field, and that it sets itself along the lines of force of that field. Now bring the needle within a foot or so of a magnet. It probably takes up quite a different position. The magnet is surrounded by its own magnetic field, and this also has its lines of force along which a compass-needle tends to point. We get a clearer idea of them by the following experiment: In a piece of board cut out a

long hollow just big enough to hold a bar magnet so that, when the magnet is put into it, its upper surface is flush with the board. Lay a piece of paper over the board, put some fine iron filings into a pepper-castor, and dust them evenly over the paper. Gently tap the board, and the filings over and near the magnet will be seen to arrange themselves in a definite pattern, really a map of the lines of force in that particular part of the magnetic field of the magnet. Just a word of caution here. A field on a farm is more or less on one level, but a magnetic field extends in every direction, up and down as well as sideways. We have seen that if a wire carrying a current is brought near a compass, the needle sets itself in a particular way. The current has its own magnetic field and its own lines of force just as a magnet has. Switch off the current, the lines of force disappear and the field is abolished. There are still two things to be mentioned about the lines. If you stand on a bridge crossing a railway and look along the rails, you will be looking "up", i.e. towards London, or "down", i.e. away from London. So magnetic lines have an "up" or positive direction, and a "down" or negative. The positive direction is that in which the north pole of a very small compass-needle placed on the line would point. Again, a magnetic field may be of any strength. Strong ones are thought of as having many lines of force to the square inch (or square centimetre), weak ones as having few. If one field is ten times as strong as

another, the stronger has ten times as many lines to the square centimetre as the weaker.

Now we can get back to the question of setting up currents—induced currents as they are called—by means of magnetic fields. When a coil of wire is at rest in a strong magnetic field, nothing happens. But if by moving the coil or altering the strength of the field there is any change in the number of lines of force passing through the coil, a current flows in the coil just so long as the change is going on. An increase in the number of lines gives a current in one direction, a decrease gives a current in the opposite one. These discoveries, made by Faraday, as to the connection between magnetic fields and electric currents had most important consequences. By moving a coil in the strong field close to the poles of a steel magnet a current can be obtained; by replacing the steel magnet by an electro-magnet the result is better.

This is the principle of the dynamo. Hosts of inventors have worked at the improvement of this machine, and it has now reached a wonderful state of perfection. It must be understood that in this, as in all other ways of producing currents, the energy or work-doing ability of the current is not a free gift. It has to be bought by the expenditure of some other form of energy. The greater the output of power from the moving parts of the machine the greater the power required to make them move. A small model may be turned by hand, but it takes some turning. The man or boy who turns the handle draws on his

reserves of energy. How does he come to have such reserves? The answer is, from the food he eats. Just as a battery is an engine in which zinc is burnt and the chemical energy of the zinc is transformed into the electrical energy of the current, so a man employed in turning the handle of a small dynamo may be looked upon as an engine in which the fuel is bread and meat, potatoes and cheese.

On the large scale we can use a steam-engine instead of a man, and burn coal or oil instead of the things used for human food. There will still be employment for the man in looking after the machinery and directing the proper working of the marvellous invention by which electric energy is obtained from that stored up in the coal. Such work is more suitable for a man. In it he shows himself master of the forces of nature. Man tames and directs these forces much as the Indian tames the elephant, and guides its great strength in doing work which a score of men could not do.

There is another great invention without which the dynamo would be of comparatively little use. It is all very well to get electrical energy, but we require to make use of it when we have got it. Now the electro-motor is a dynamo working backward. In the dynamo you start with mechanical motion and get current; in the electro-motor you start with current, and get wheels to go round and things to move. It can thus be used for doing all sorts of mechanical work, such as lifting weights, moving trains and

tram-cars, grinding corn, pumping up water, or crushing ores. I have already said that the current in a coil flows first in one direction then in the opposite, according as the lines of force through it are increasing or decreasing in number. In the armature coils of a dynamo, as they are called, the current alternates in this way, and in the main circuit outside the dynamo it often does so as well. Such an alternating current —A.C. for short—is quite suitable for some purposes, but for others it is necessary to have a direct current, known as D.C. Now this difference between currents, the D.C. that flows always in the same direction and the A.C. that is a to-and-fro surging of electricity, is by no means the only kind of difference between one current and another. To understand another very important difference it is helpful to compare the flow of electricity with the flow of water. Suppose water running in two pipes. A gallon of water a minute passes a point in the one, two gallons a minute pass a point in the other. We might say that the water current in the second was double that in the first. So the electric current in one wire may be double that in the other, and then an engineer would say that the amperage of the first is twice that of the second. But the flow of water in two pipes might be the same as regards quantity and yet very different as regards pressure. One pipe might come from a cistern a few feet from the ground, the other from one at the top of a lofty water-tower. Make a tiny hole in the first, and you can stop the leak with a bit of chewed

bread; from a similar hole in the second the water would gush out with great force, and you could not, perhaps, check it by pressing your finger on the hole with all your strength. There is a difference of like kind in the case of electric currents, a difference of electric pressure or voltage. If we want to describe a current we have to know its amount in amperes and its pressure in volts. Its power, or rate at which it can do work, depends on both. We may describe it as of so many watts, the watts being got at by multiplying amperes and volts together. Thus a tenth of an ampere at 500 volts, one ampere at 50 volts, and ten amperes at 5 volts would all give 50 watts. An interesting and important part of the history of electrical engineering is that which describes the invention of instrument after instrument for the accurate measurement of amperes, volts, and watts. These are called ammeters, voltmeters, and wattmeters. The meter which measures the supply of electricity to a house for lighting and heating purposes records the number of "units" or "Board of Trade units" supplied. This unit represents the amount of work that can be done by 1000 watts in an hour.

Dynamos need not be driven by steam-engines. In some countries, notably Norway, there is abundant water power, and much of this is now used for electrical purposes. By means of the turbine, which does far better and more economically what the mill-wheel of an old-fashioned water-mill can do, the giant power of the great Niagara is made to labour for the service

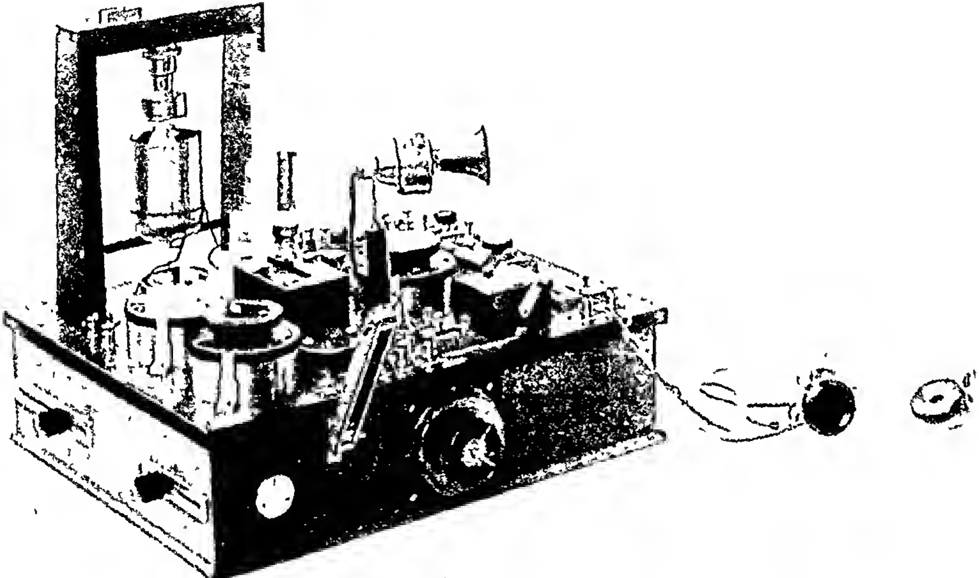
of man. The Germans have a good deal of water power also, and they have made great use of it in this way. But electric energy can not only be used at or near the waterfall where it is generated, but it can be sent to great distances and used where it happens to be wanted. This is made possible by means of another group of electric inventions, the transformers. From a current of a certain voltage and amperage we can, by a "step-up" transformer, get another having a higher voltage and a smaller amperage. On the other hand, by a "step-down" transformer a small current of high voltage can give rise to a larger one of lower voltage. Thus by the side of a great waterfall may be established a generating station where dynamos, set in motion by water power, produce a current. The step-up transformer uses this to set another flowing, much smaller, but of great voltage. This can be economically transmitted through a comparatively slender and inexpensive copper cable to a distant place. Step-down transformers reduce the voltage and increase the amperage to safe and convenient values. The current thus obtained is used for electro-motors which drive machinery for grinding corn, sawing wood, working cranes, and all sorts of other purposes. In England we have not so much available water power as some other countries, but we still have large supplies of coal. It is probable that as time goes on there will be a great deal more done in the way of using the coal close to the pits and sending, not the coal itself, but the mysterious energy locked

up in it, which ages ago was absorbed from the sun's rays, to distant towns, villages, and farms where it will be set to do various kinds of work. One of the most important of all electric inventions was that of the telegraph. It affects all of us, I suppose, every day, although we may not often send or receive a telegram ourselves. News of what happens in one place is sent all over the world by an invisible messenger which travels at a pace compared with which the speed of a race-horse or a rifle bullet is like that of a lame snail. A speech is made in Parliament, perhaps, and before the speaker has finished, the grocer in a country town hundreds of miles from London has put 2*d.* a pound on the price of his tea. The idea of using electricity to send messages to a distance was thought of a long time ago, and Bishop Watson, in 1747, sent the discharge of a Leyden jar through 10,000 feet of wire. This, however, was one of a good many false starts, and it was about ninety years later when the first really useful systems were set up on the London and Birmingham and the Great Western Railways.

Five needles were used, and each needle was worked by two wires; but this system did not last long. It was soon found that two needles were enough, and later on the single-needle instrument came into use. It was also discovered that it was not necessary, in sending a message from London to Birmingham, to have one wire to carry the current and another to bring it back. One of the early inventors, named

Steinheil, thought he might be able to use the railway lines instead of a return wire. He made some experiments to see whether this plan would work, and found that the earth itself would serve as a return wire. It may not be literally true that the current finds its way back through the earth like a mole burrowing with the speed of lightning, but the effect is the same as if it actually did so, and there is naturally a great saving in the cost of wire. The inventions that have been made in connection with the telegraph would take a book by themselves to mention. Some have had to do with the transmitting instrument used by the clerk who sends the message, others with the apparatus for receiving it. Besides the old-fashioned needle which moves to the right and left, there are sounders which tick out the message, and printers which make dots and dashes on a strip of paper, or actually, as in the Hughes type printer, print in ordinary letters. Still more wonderful is the autographic telegraph, which reproduces the very handwriting of the original dispatch. Other inventions have dealt with the line or wire, its construction, material, and insulation. Accidents happen; there is a leak somewhere, and it is necessary to find out just where the fault is, so that it may be put right. The best ways of doing this have been provided in yet another class of inventions.

Another very wonderful discovery was that of the possibility of sending a number of messages at the same time over the same wire. Several systems of



A WIRELESS-TELEPHONE TRANSMITTER AND RECEIVER

The Marconi Company, by whose courtesy the above photograph is reproduced, have succeeded in conveying speech by wireless telephone from Ireland across two thousand miles of sea to Nova Scotia.

Conq. VIII.

duplex, quadruplex, and multiplex telegraphy have been devised; the earlier did not work very well, but the difficulties have gradually been overcome. The currents required for telegraphic work are small, and the battery has been able to hold its own as the most convenient source. In the Central Telegraph Office in London there are many thousands of cells in use, and although they are very different from the original cell of Volta, yet they are really direct descendants of it.

When it was first proposed to make a cable to reach all the way from Europe to America, to lay it safely along the ocean floor and use it for sending messages from continent to continent, the suggestion must have seemed rather wild. Back in 1850 a cable was really laid between Dover and Calais, but this got rubbed against rocks and only lasted a few hours. This was not encouraging, but the bigger thing was successfully done, and the first Atlantic cable was laid in 1865–6. Even when the cable was safely laid the difficulties were not over. The ordinary receiving instruments were no good, but fortunately we had at the time one of the greatest men of science that our country has ever produced. This was William Thomson, afterwards known as Lord Kelvin. He invented an extraordinarily sensitive instrument called the reflecting galvanometer, which answers to the very feeblest of currents. If you hold a bit of looking-glass so that light falls on it, you may notice a spot of light reflected from it to the ceiling or wall.

A very small movement of the hand will make the spot jump quite a long way; you can hardly hold your hand so still that the spot will not move at all. In the reflecting galvanometer there is a little bit of magnetized watch-spring fastened to the back of a very thin circle of silvered glass smaller than a three-penny-piece. This is hung by a fine silk thread in the middle of a coil of wire. A ray of light from a lamp falls on the mirror and is reflected to a scale. When a tiny current passes through the coil the little magnet moves a little, and the spot of light on the scale moves very much more. This is only one out of a very great many inventions of Lord Kelvin. Another is called the siphon recorder, and both can be used for receiving messages by cable. The whole world is now pretty well linked up by these cables, so that our morning papers bring us news of what happened the day before in almost all parts of the earth. The total length of under-sea cables is now not far from a quarter of a million miles, and millions of messages are transmitted every year. The invention of the telephone was a great step forward in the art of communicating with people at a distance. It makes us able to talk to them, and it is often easier to explain things by word of mouth than by writing or any kind of signalling. You speak at one end of the line, and the person at the other end hears what seems to be your voice. But the voice does not really travel along the line; what happens is something like this: When you speak you set up in the air the vibrations

which are the cause of sound. The transmitting instrument into which you speak is affected by these air vibrations, and in turn affects the current in the wire. The strength of the current rises and falls in tune with the air-waves, and these variations cause vibrations in a thin plate in the receiving instrument at the other end of the line. The quiverings of the plate set the air in motion, and the person who is listening hears a sound which is like your voice. The whole thing reminds one of the House that Jack built. The voice of the speaker affects the air, and the air affects the transmitter, and the transmitter affects the current, and the current affects the receiver, and the receiver affects the air, and the air affects the listener.

The telephone as we have it now was not invented straight away, but, like most things of the kind, has grown up gradually. Its first beginnings were in 1861, when a German named Reis invented an apparatus for reproducing sounds by electro-magnetic means; but the names of Graham Bell, Hughes, and Edison will always be remembered as those of the men whose inventive genius led to the growth of the telephone from the toy of 1861 to its present position.

At the beginning I said that sometimes a discovery is made by accident. It is as if a man stumbled over a stone, and then found what he took for a stone was really a nugget of gold. But it is perhaps more usual for discoveries to be made by those who are

looking for them and have some kind of guidance as to where to look. A very good example of this is in the great discovery of what is often called "wireless", or, more correctly, radio-telegraphy. A very great English mathematician and electrician, Clerk Maxwell, came to the conclusion in 1867 that there was a very close connection between electricity, magnetism, and light. It was already believed that all space, between star and star, sun and planet, as well as between the particles or atoms of matter, was filled with a something known as ether. This can be set quivering or vibrating, and the light and heat which reach us from the sun are really waves or vibrations in the ether. They travel with enormous speed; about 186,000 miles in a second; but the waves themselves are very short indeed, so that in yellow light, for example, there would be more than 43,000 in the length of an inch. Waves of red light are a little longer, and dark waves, which can give us the sensation of heat but not of light, are longer still. Maxwell thought very much longer waves could be set up by, for example, the discharge of a Leyden jar. The human eye could never detect such waves, but it might be possible, perhaps, to construct some kind of electric instrument which would be acted on by them. In 1888 Heinrich Hertz invented a very simple apparatus by which he could not only produce such waves as Maxwell had spoken of, but also detect them. These waves, he found, can pass through stone walls as easily as light-waves pass through glass. Here

was the germ of radio-telegraphy. Sir Oliver Lodge invented an arrangement called a coherer which enabled him to make a much better detector of the waves, and numerous other inventions followed. The oscillators, the apparatus for starting the waves, or "making a splash in the ether", were greatly improved, and thus signalling over quite long distances became possible. Marconi did a very great deal towards making radio-telegraphy really work on the big scale. He scored a great triumph when, in 1901, he was able to detect in Newfoundland waves started in Cornwall, more than 2000 miles away.

It is hardly possible to say which aspect of life is most affected by the development of wireless telegraphy and telephony. Obviously, of first importance is the application of wireless for the safeguarding of life, and the provision of wireless receiving and transmitting apparatus to ships has, during the comparatively few years since its adoption, been the means of saving many thousands of lives. Only seventeen years ago the world was thrilled by the first great story of wireless telegraphy, when in January, 1909, the *Republic* was sunk off Nantucket. For several years before this date wireless had been installed upon the larger ships, and those interested either in wireless or in shipping had every reason to foster the new means of communication, but to the general public the whole subject was too obscure to receive much attention. The sinking of the *Republic*, when nearly 800 lives were saved solely by means of

the wireless appeals for help sent out by the operator on board, Jack Binns, made a profound impression, and from that moment no one, however hidebound or unimaginative, could afford to dispute the immense possibilities of wireless. If further demonstration were needed, the undying story of the loss of the *Titanic* in 1912, when for two frenzied hours the operators on board dispatched message after message to all the ships within call, would have proved for all time that wireless telegraphy should be considered as an essential part of the equipment of every ship. Over 1500 souls sank with the *Titanic*, for the nearest ship to pick up the "S.O.S."—letters which then for the first time burnt their tragic import into the public mind—was 70 miles away at the time she received the first call for help, and reached the scene of the disaster nearly two hours after the liner had sunk. Other ships soon arrived, and between them the sad task of rescuing the 700 survivors from the over-crowded boats was achieved. But without the aid of wireless telegraphy, and the heroism of the operator, Phillips, who went down at his post, it may be doubted whether any lives would have been saved. The knowledge that their plight was known, and that rescue was coming at the highest speed of over-driven engines must have brought confidence and courage to many timorous souls that would otherwise have spread panic and destruction. For apart from its practical value, the presence of wireless apparatus at sea has the effect of improving the *morale* of

nervous passengers, as was proved over and over again during the war.

Of course, the war itself was responsible for very rapid developments in the uses of wireless telegraphy. Needless to say, Germany was the one Power involved which had prepared wireless stations in advance. Everyone who saw it remarked upon the enormous wireless station erected at Nauen, near Berlin, in the early part of 1914. "Such a thing will never pay," said the wiseacres. "The company that is building that will surely come to grief." But the Nauen station bided its time until the very eve of "Der Tag", when it transmitted a special code message. The world at large knew and cared nothing about it, but all German ships at sea in all parts of the world recognized it as the word they had been warned to expect. Each and every one scuttled for the nearest neutral harbour, and thus Germany saved her shipping. Nauen station stood revealed as a world broadcasting station. Throughout the war it scattered Germany's account of the position, Germany's propaganda generally, all over Europe and to America. France retaliated through her Eiffel Tower station, but she had only the range of Europe. It immediately became necessary to intercept regularly and unremittingly, the enemy messages. This was an integral and little appreciated duty of the war. It can never be known how often our relations with other countries were strained almost to breaking-point by the outpourings of Nauen, nor how often

they were re-established by the diplomacy of those responsible for our own broadcast propaganda.

The part played in the war by wireless telegraphy —wireless telephony had not then come into its own —needs a special book to itself, so many and so remarkable were its ramifications. Certainly amongst heroes of the war should be mentioned the wireless operators who, not content with transmitting information from aeroplanes in the day-time, even insisted upon being dropped at night behind the enemy's lines by means of black parachutes. Once there, they frequently had to depend upon their own ingenuity to get out again, but to them the important thing was the dispatch of useful information; their own safety was regarded as a secondary matter.

Now, however, we are in the fortunate position of being able to concentrate on the development of wireless for peaceful purposes. In fact, the interest in broadcasting is so universal that for the moment it obscures, in the public mind, other aspects of wireless activity. To most persons broadcasting arrived with startling suddenness, for apparently no sooner did it become possible than it was taken up with enthusiasm by all countries, and by all ranks and conditions. It was as though the world went to bed one night content with its gramophone, and awoke the next morning to find aerials in every back yard. Intervening stages there were, of course, and it is interesting to trace how the present high standard of production was reached. To do this we must go back quite a long way.

Wireless telephony was regarded as a feasible proposition in the last century, and very early in the history of the present century speech was actually transmitted without wires across a mile of space. But until recent years the obstacle to a practical or everyday use of wireless telephony was the difficulty of creating continuous ether waves. For telegraphy, the waves used were intermittent—Hertzian waves—but intermittent waves, though serviceable for transmitting Morse signals, were useless for the transmission of speech or music. In 1900 a very ingenious arrangement was put into practical use by Mr. Duddell which has come to be known as the "singing arc". This is carried out by means of an ordinary arc lamp, the flame of which is caused to move backwards and forwards between the carbon points, thereby setting up a "singing". The process of "singing" generates, in an aerial wire, continuous electric waves which provide a natural path for the transmission of speech. In the light of our present knowledge there is nothing surprising in this, but twenty-five years ago the fact that a man in England could speak to a man in Denmark without the aid of telephone wires was amazing and wellnigh incredible. Unfortunately, further developments of the singing arc did not materialize, owing to the untimely death of Mr. Duddell, though his ideas were improved upon by the Danish Professor Valdemar Poulsen.

Between 1900 and the outbreak of the war, interest in various applications of wireless telephony, some

of which now seem only amusing, was very great, though the general public was as sceptical as it had been, ten years earlier, of "them motor cars". There was, for instance, the Railophone, which was expected to revolutionize train control and to abolish railway collisions for ever. Every train was to dangle a short length of electric wire which would hang about eighteen inches above a second wire travelling along the railway track. The current jumped the eighteen inches between the two wires, when set in motion by the person using the mouthpiece within the train or at the other end of the fixed wire. Another was the Aerophone, which in 1911 was used for the purpose of communicating with aviators. Yet another was a portable wireless telephone, invented by Mr. A. W. Sharman, very light and compact in weight, and capable of transmitting the voice over several miles. Wireless apparatus of this type was in use during the war, but not to any great extent.

In fact, a still further difficulty in the path of the would-be improver of wireless telephony during the first years of the century was the mouthpiece. Many and varied were the devices which were tried in the endeavour to strengthen the electric current set up by the voice when speaking against the microphone, but no really reliable means of doing so was discovered until the invention, by Dr. Fleming, of the "thermionic" valve. In Germany, experiments had been made with the "Lieber" valve, to such good purpose that in 1914 Berlin and London were successfully

in communication by means of wireless telephony.

It is probably true that a great industry has never sprung so quickly into prosperous activity as that which has grown up in the four years following the introduction of "broadcasting". Until 1922, or thereabouts, the only wireless enthusiasts were to be found among some scattered bands of amateurs who were interested far more in the scientific aspects of "broadcasting" than in the rather remarkable concerts flung into the ether by Captain Eckersley and his co-workers from the little station at Writtle. There was great wisdom in the action of those interested in the manufacture and distribution of wireless apparatus in putting their heads together to form the British Broadcasting Company. They foresaw that, from being the hobby of a few, broadcasting might quickly become the entertainment of millions. Negotiations with the Postmaster-General for the right to broadcast, and also with the Marconi Company for the use of certain patents, were carried through with a minimum of friction and delay, the ultimate result being a licence granted to the British Broadcasting Company from 1923 until 1926. Several factors have been at work to make broadcasting such an immediate and pronounced success; not least of them the consistent policy of the B.B.C. in maintaining a high standard of entertainment calculated to appeal to the widest circle of listeners. The wonder of wireless, with its immediate grip of the imagination, has helped, of course; and equally important is the remarkable fact

that a most complicated scientific marvel is revealed as a commonplace by the cheapest and simplest of instruments. If you live within the "crystal range" of a broadcasting station your receiving apparatus need not have cost you more than a few shillings.

We must not allow the amenities of broadcasting to blind us to the wider and more serious uses of wireless. Already a girdle of high-speed commercial wireless on a short wave-beam system is about to encircle the Empire. Four great new Marconi stations at Bodmin, Bridgwater, Grimsby, and Skegness are transmitting and receiving from Canada and South Africa, India and Australia, and Imperial communication on a scale hitherto undreamed of has become an accomplished fact. A feature of these new stations is the gigantic lattice-girder masts that have been built. At each station there are ten masts, five for communication with each dominion. The five masts are erected in a straight line at right angles to the direction in which communication is to be established. They have a height of 277 ft., with a cross arm at the top measuring 90 ft. from end to end. The distance between the masts is 650 ft., and the length of the whole system for each transmitter about 3500 ft.

The era of commercial transatlantic telephone communication was brought appreciably nearer on the fiftieth anniversary of the day in March, 1876, when the patent was granted to Dr. Graham Bell for his invention of the telephone. On this highly appropriate

occasion, groups of engineers and journalists in London and New York talked to one another for some hours, with perfect clearness. The great Rugby station transmitted the London speakers on a wave-length of 5770 metres. The Americans talked back on a different wave-length, caught on a straight line of wire, three and a half miles long, at a little "secret" station at Wroughton, on the Wiltshire Downs. The marvel of the flawless reception on both sides that specially distinguished this from all previous experiments lay in the work of the men at this unpretentious little Wroughton station. It was their job to control the voice from across the ocean. As the signals from the American station vary in strength, so they are corrected or modified to make the speech continuously clear on the underground wire to the listener in London.

One of the most interesting developments of wireless telegraphy is that which has "television" as its object. For many years past inventors have striven to perfect apparatus by which pictures could be telegraphed to a distance, and some of the daily papers have actually reproduced photographs sent "over the wire". Unfortunately the apparatus has been both costly and cumbersome and not very reliable. All the systems have been based on the peculiar properties of selenium; and the necessity for employing a screen consisting of a very large number of selenium cells, each of which has to be separately energized, involves most complicated electrical con-

nections. But at the close of 1925 the members of the Royal Photographic Society were treated to a demonstration which aroused the greatest interest among wireless experimenters. This was the demonstration by Mr. Thorne Baker of a system of transmitting and receiving wireless pictures that is a very important step forward to the day when we shall assuredly "look-in" as well as "listen". Indeed, Mr. Baker declares that if the British Broadcasting Company chose to broadcast pictures, anyone with a loud speaker could receive them as easily as they now receive sounds. But again we are behind America, where apparatus is actually on sale by which amateur wireless enthusiasts can send out from a small transmitter photographs which their friends can receive.

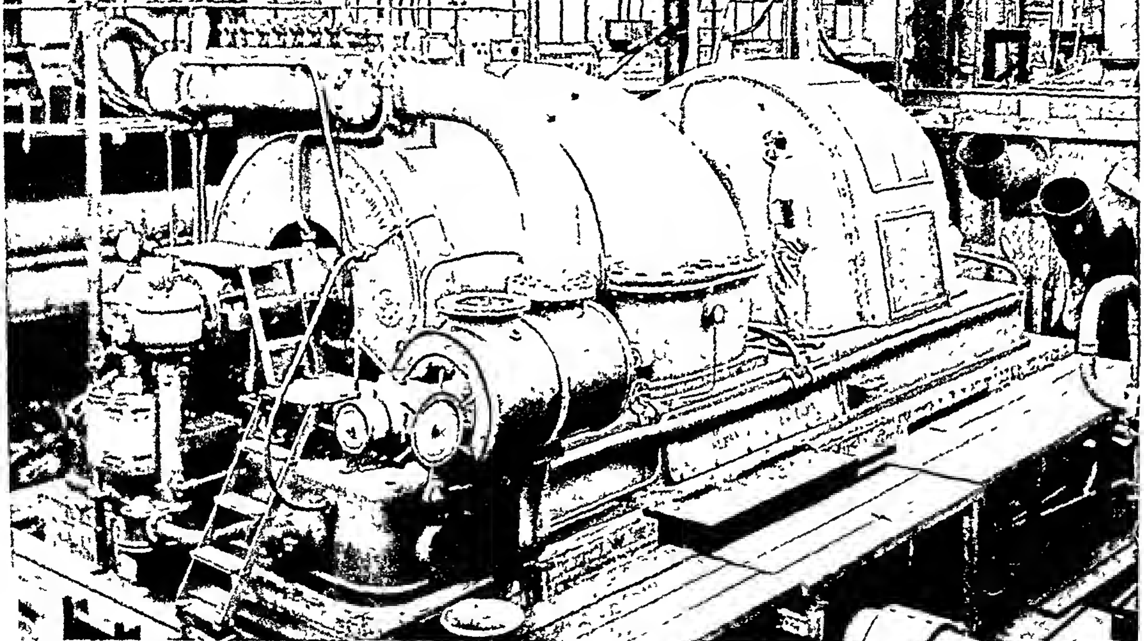
One may not close this chapter without reference to one of the most useful of all electrical inventions—that of the flaming arc, which does a great deal more for us than we ever imagine, by placing at our disposal the fiercest and most easily controlled furnace known to us. Sir Humphry Davy discovered that if two pieces of carbon, joined by wires to the poles of a very powerful battery, were allowed to touch each other so as to start a current, they could be pulled a little way apart without stopping the current. It is carried across the gap by an arch, as he called it, a kind of electric flame. The ends of the carbon, especially the positive one, become white hot, and an intensely bright light is produced.

Although this discovery was made more than a

hundred years ago, it was a long time before use could be made of it. In the first place, the dynamo had to be invented, so that the necessary current could be got cheaply. Then mechanism was required to bring the carbons together to start the current, to pull them apart to just the right distance to start the arc, and to keep them at this distance in spite of their gradually burning away. All these difficulties were got over, and the arc lamp is much used for street lighting and for railway stations and large buildings. But lighting is not the only use of the electric arc. We know no other way (apart from complicated chemical reactions) of getting so high a temperature, and in the electric furnace this high temperature can be used for a variety of purposes requiring intense heat. By means of this furnace the French chemist Moissan and Sir William Crookes were able to make diamonds. They were very small, but real diamonds, not imitations. Metals like platinum can be melted with the greatest ease, and even rubies become liquid in the furnace. The carbide of calcium, used for producing acetylene gas, is made in the electric furnace; so, too, is aluminium, that exceedingly valuable metal that is now put to so many uses that were unknown until, within comparatively recent times, electrical means became available for smelting the intractable bauxite.

At the intensely high temperature of the electric arc the nitrogen of the air can be made to burn, and from the gas so formed nitric acid can be made. To

do this on a large scale a very special kind of arc is required. In one process, the Birkeland Eyde, the arc is a great flat disc of flame about 6 ft. across. In another, the Schönherr, the arc is produced in a tube, and is as much as 20 ft. long. Nitric acid is the basis of nearly all the high explosives used in modern war, and its manufacture by the Germans on a practical scale during the Great War undoubtedly contributed to the prolonging of that catastrophe. But nitrogen has a higher use, for it is a vital element of plant food; and the recovery of nitric acid from the air, ultimately to be made available for feeding crops, is one of the most wonderful and most hopeful achievements of modern science.



By courtesy of The British Thomson Houston Co., Ltd

A DYNAMO DRIVEN BY A TURBINE

The turbine is here employed in the economical generation of electricity.

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CHAPTER IX

Photographic Inventions

We are all of us photographers. But very few of us know anything about photography. By which I mean, of course, not the taking of a snapshot and the subsequent operations required to produce the finished print, but the science of optics and the chemical action of light. We are not going to trouble about that now; in this chapter we are going to rush across an enormous field of endeavour—so big, indeed, that we cannot see the confines of it, nor imagine them. And the amazing thing about this field is that it has been laid out entirely in a period of no more than eighty years. There's romance for you! Neither the steam-engine nor the greater field of electricity can boast of as rapid a career. The explosion-engine fails to affect and influence our lives at half as many points as does the camera. Did one never take a photograph, nor have one taken, did one never pay a visit to a picture palace, did one never see an illustrated book or paper, had one not the least interest in natural science—however determinedly one said "I won't be bothered by photography"—photography would have him on the hip before he was aware of it. Be he well or ill, his

health is safeguarded by photography applied to the microscope. Does he ever travel or trust himself to any machine, or something made by a machine? The same combination has helped to ensure his safety. And every time he avails himself of the knowledge brought to us by astronomers (as he does far more often than he imagines) he is unconsciously admitting his indebtedness to photography. Indeed, to exhaust the list of ways in which the camera influences our daily lives would be a long and an exceedingly tedious task. Even the artist of pencil and brush, that he may secure accuracy of detail, must often condescend to the study of pictures by his more exact brother-artist Light.

Photography of course is closely connected with the study of optics, and optics was a science which had made some progress in the Dark Ages. Astrologers and others who fattened on the credulity of the public were no doubt fully alive to the possibilities of mystery-making by mirrors, and the A B C of reflection must have been well understood. The camera obscura was invented by Della Porta in 1569, and a little later it was discovered that horn silver (*luna cornea*) would turn black when exposed to the light. Thus side by side occurred the two events which made photography possible, though at the time there seemed no connection between the two.

Thomas Wedgwood and Sir Humphry Davy actually succeeded in making sun-pictures at the very beginning of the nineteenth century, but as they

knew of no methods of fixing their pictures it must be admitted that they did not carry the science far beyond the point at which it stood already. Both were interested in other directions, but both were men of such remarkable talents and foresight that it seems strange that they should not have made more progress. Many years had to pass before anything of great importance was achieved.

To two Frenchmen of the early nineteenth century belongs the honour of laying the foundation stone of practical photography. Like all our great inventors they were amazingly patient, industrious men, for whom no toil was too great, for whom each year brought bitter disappointments and small rewards. One of them, Nicéphore Niépce, died before there was anything tangible to show for his long efforts after heliography or sun-drawing, and it was left to his partner, who subsequently gave his own name to the process worked out between them, to startle and amaze the world with pictures "drawn by Nature". This was Louis Daguerre, who was responsible for one of the most romantic discoveries known to science.

Daguerre was a scene painter of Paris, a man of active brain and restless temperament, who was obsessed with the desire to "fix" the pictures of the camera obscura. He had made countless experiments before his meeting with Niépce; indeed he was so much addicted to experiments, and seemed to have so little time for the commonplaces of life, that his

wife felt herself justified in calling in physicians to say whether he was going mad. Surely the poor man was wasting his time and money, and making himself ridiculous to boot, in striving after what could never be attained!

Our grandfathers and grandmothers—or those of them who were wealthy enough and bold enough—had their portraits taken by Daguerre's process. It must have been a horrible ordeal. The sitter had to keep motionless for about twenty minutes, and if the sunlight was not over good probably had to submit to having his face whitened in order that it might reflect more light! The result was a very soft and very artistic "photograph", but probably not a very satisfactory "likeness", on a plate of burnished silver. The picture is a positive—that is to say, white is white and black is black—but it is necessary to hold it so that no bright light strikes it before it can be seen with any clearness. The secret of the daguerreotype—which must not be confused with the later and vastly inferior "tin-type"—was this: The silver plate was treated with iodine vapours before being placed in the camera. On exposure the rays of sunlight reflected to the plate by the "high-lights"—the white and bright parts of the picture—decomposed the iodide of silver. The picture was there, but it was invisible. The problem was, how to bring out the latent image. Poor Daguerre tried this and tried that, worried his wits and wasted his chemicals, but without success. The secret was revealed to him at

length, not by his own efforts, but in a very wonderful way. An accident developed Daguerre's photograph for him.

He had taken from his camera one of the silver plates—which, though it had had a long exposure, had nothing to show for it—and, with a deep sigh, no doubt, put it in a dark cupboard wherein he kept his chemicals, to remain out of the way until he should have time to repolish it. But next day, when he went again to his cupboard without a thought (unless it were a sad one) for the spoilt silver plate he had put there, this very plate thrust its presence upon him. He seized it, gaped at it, pinched himself to make sure of his material presence, and dashed away crying (at least, so we are told): "I have seized the light, I have seized the light! The sun himself shall draw my pictures!" For there, on the spoilt plate, was all that the patient artist had been striving for—a perfect picture!

What was there in the cupboard that had performed this magic? Daguerre reasoned that one or other of the chemicals in the cupboard must have acted on the latent image and "brought it out". It remained to discover which one, but a simple process of elimination would soon lead him *to it*. Another plate was exposed, taken from the camera, and locked up in the cupboard. And sure enough, next day, the magic cupboard held another perfect picture. It was marvellous. The process was repeated, a dish of chemicals being removed each time a fresh plate was put in the

cupboard, until at last there remained but one dish, which was bound to hold the secret. It was an unsuspected secret too, for the dish held mercury, and Daguerre was for a long time at a loss to account for its subtle power on his plate. What really happened was that the mercury gave off a vapour that attached itself to the plate in exact proportion as the sunlight had decomposed the iodide of silver.

And so came about photography. The world was very much impressed. A commonplace to us, this development of the latent image: in 1838 it was really rather staggering. The newspapers were full of Daguerre. "Why," cried one Paris paper, "in a view of Paris we can even count the paving stones!"

While the patient Daguerre was working in France an Englishman named Fox Talbot was also seeking to fix the beautiful image of the camera obscura. Without knowing it, Talbot covered much of the ground that Daguerre had already traversed, but his process, which was made known almost simultaneously with Daguerre's, was in one respect greatly superior to the Frenchman's. Daguerre could supply but one copy of each photograph taken—the exposed silver plate itself. Fox Talbot used paper treated with silver salts, and by making the paper transparent by oiling it after exposure he was able to print from this negative as many positive copies as might be required.

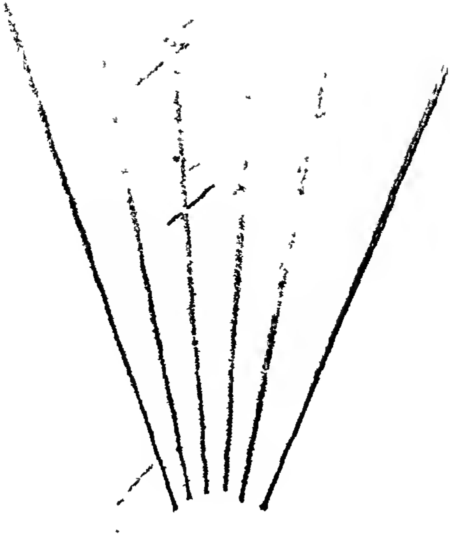
For some ten or twelve years, until 1851 to be exact, Talbot-type and Daguerreotype held the photo-

graphic field, such as it was. Then came a great improvement, the introduction of a sensitized glass plate. An English sculptor, Frederick Scott-Archer, had been experimenting with a new substance called collodion, obtained by dissolving gun cotton in methyl-alcohol, as a vehicle for the chemicals acted on in the camera. Scott-Archer's process was taken up everywhere—he himself opened a studio in London, and photography that had hitherto been a curiosity became a commonplace. The wet collodion process was a messy business. Great skill was required in the covering of the plate, which had to be exposed and developed before the chemicals dried. I have written "*was* required", but the process is still used in "process photography", that is, the making of photographic blocks for mechanical printing. Poor Scott-Archer got nothing for his invention, other men reaping the reward of his researches; for he omitted to patent his process and died in poverty.

Now that we are on this subject of the wet collodion process it may be worth our while just to see how drawings and photographs are reproduced for the printer. This surely — the power of the printing machine to put into the hands of thousands, or it may be millions of people, some beautiful or interesting picture—is one of the most beneficent developments of photography. The making of a line block—that is, a block on which there are only black lines and no half-tones, the fine gradations of light and shade,

such as give body to a photograph or a painting—is a simple and rapid business. You can take a pen-and-ink sketch to the process-engraver and he will produce a block of it before you have had time to finish a cigar. He pins your sketch to a big screen, focuses it to the size you need your block to be, prepares a wet collodion plate in his dark room, and exposes it in his camera. The camera is not quite the same as that generally used—it is more like an enlarging lantern—and a queer thing about it is the position of the lens, which is placed at right angles to the plate and in front of a mirror, so that the light from the drawing on the screen is thrown on to this mirror and from that to the plate. A roundabout way of taking a photograph, you think? Think again, and you will see that, as the finished block which the printer uses must be the reverse of the original—that is, the right-hand side of the one must be the left-hand side of the other—the negative that is now being taken must be the right way round, for it is from this negative that the final block is made. Hence the necessity for the reversal of the image by the mirror in the camera.

Having photographed your sketch and developed his negative the block-maker proceeds to print from it. He puts in his printing frame, not a sheet of paper such as you print upon, but a sheet of zinc covered with a very thin layer of chemical emulsion. Now the light from a powerful lamp striking through the clear glass of the negative, which corresponds



TELLING THE WORLD GREENWICH TIME BY WIRELESS

A photograph of the Eiffel Tower taken during the despatch of wireless time signals The ultra violet radiations, although invisible to the naked eye, appear luminous on the photographic plate

Page 1[illegible]

to the black lines of your sketch, renders the emulsion insoluble; but where protected from the light by those parts of the negative which, being opaque, resist the light rays—these are the white parts of the sketch—the emulsion on the sheet of zinc remains soluble.

These soluble parts of the film are next washed away; then the block receives a coating of printing ink, and is placed in a bath of acid. The acid etches or eats away the zinc where it is not protected by the insoluble film and the coating of greasy ink. When the etching has proceeded far enough the black lines of your sketch stand well up above the surrounding surface of the block.

Such, in very bald outline, describes the making of an ordinary zinc "line" block. The blocks used for printing half-tone pictures are produced upon a similar plan, but with one very important modification. It is quite obvious that by the process just outlined we can only have on our block black and white. How are we to put on to a metal plate all the myriad inequalities of surface that are needed to show us, when we ink the plate and press a piece of paper against it, every variation of shade? The manner in which it is accomplished is a very striking one. The photograph is divided up into thousands of sections, and to do this the block-maker uses thousands of cameras. Thousands? Millions, rather! True, as far as the onlooker can see, there appears to be only one camera, with only one lens. We must look inside his camera if we want to see the millions of other cameras.

They exist as an amazingly fine network interposed between the lens and the plate. This network (it is called a process screen) divides the picture into a multitude of dots, which vary in size according to the amount of light that has been reflected from any one portion of the picture. Take a magnifying glass and look through it at one of the illustrations in this book —or, better still, in a daily paper: you will be able to distinguish the dots into which the picture is broken up. And you will see that in the high lights they are very, very small, so small that they have taken up so little ink that you can hardly see them, giving the impression of almost pure white. In the half-tones the dots are a little bit bigger, they have taken up a little more ink; while in the very dark parts of the picture the dots are so big that they have taken up a great deal of ink. The process screen is composed of two diagonally-ruled glass plates, placed face to face, so that the lines cross and give the effect of very fine gauze or netting. There may be sixteen lines to the inch for very coarse work, or one hundred and eighty or more to the inch for very fine work. That will depend on the rate at which the block is to be printed from, and the quality of the paper.

The illustrated daily paper could not exist without photography. But it is not many years since *The Daily Graphic* was rightly thought to have achieved something very wonderful when it presented its readers with a photographic reproduction of an event that had happened the previous day. Now, however, nobody

would be very much surprised if a daily paper came out with its half-tone illustrations in colours. True, such illustrations would have to be in the form of a supplement, and they would not be strictly topical, for they would take much longer to prepare and to print than if they were ordinary half-tone blocks. All the same, ninety-nine hundredths of the coloured pictures we see owe their existence to the process screen just described, and it is not a very big step from the ordinary half-tone process to the ubiquitous three-colour process.

The three colours referred to are red, blue, and yellow, and they are the primaries for *pigments*. It is common knowledge that these three colours and their combinations give *all* the colours. If we can get three blocks, therefore—a red, a yellow, and a blue—we can reproduce all the tints of the picture to be reproduced, a water-colour sketch let us say. To get these blocks we have to make use of another set of primaries—red, green, and violet. They are the primaries of *light*; that is to say, rays of these three colours together make up white light. So we get three filters, a red, a green, and a violet, and take three negatives of our picture. Then we find that the negative taken through the red filter records only the blue rays; that through the green filter only the red rays; and that through the violet filter only the yellow rays.

It is therefore only necessary to make a block from each of the negatives, and to print from them in

turn, using the three primary *pigments*. The first block is printed in yellow ink, the second is printed in red on top of that, and the third on top of the other two in blue ink. I see that I have said that it is "only necessary" to perform these three printings on the same paper to reproduce the original, and although the statement is true, I am afraid it may be misleading. So I hasten to explain that all processes of photography in colours are highly scientific, and that all the operations in them must needs be carried out with great care and accuracy. In the making and printing of three-colour blocks, for instance, the colour filters, the screens, the pigments used, are constantly subjects for scientific investigation and improvement. And the printer must be an expert craftsman, and an artist into the bargain.

The three-colour process of photographic reproduction is really the most satisfactory attainment that has been reached in the effort to catch and fix "natural" colours by the camera's aid. I have seen a three-colour print done from actual fruit and flowers, and a three-colour reproduction of a famous painting that were faithful enough to satisfy the most captious critic. Of course, photography in colours has been the philosopher's stone of all photographic experimenters. Pictures in black-and-white are very beautiful and instructive, but how much more beautiful is the little picture in the camera's view-finder! As long ago as 1839 the great French scientist Arago thus expressed himself: "The image in its natural and

varied colours may remain long—perhaps for ever—a thing hidden from human sagacity. But let us not rashly circumscribe knowledge within impassable bournes. The successful efforts of M. Daguerre have disclosed a new order of possibilities." Truly colour has proved an elusive quality, for only now are photographers beginning to enmesh it.

So long ago as 1895 a process of colour photography was made public, but it was by no means the ideal process for which the world was waiting. Frederick Ives, a native of Philadelphia, was responsible for its initiation, and it consisted of three plates—yellow, red, and blue—viewed simultaneously by means of a magic lantern. A better effect was obtained by the use of a pair of photographs, as used in a stereoscope, of each colour, these being inserted in a little instrument with a terrible name—the *stereophotochromoscope*. The three sets of slides when looked at through this overweighted little piece of apparatus produce a charming little picture. Ives also used a special camera of his own design for taking the photograph through three coloured screens simultaneously. A Dublin experimenter, named Professor Joly, has obtained good results by another method. Instead of using three separate coloured screens, he started with a clear glass screen. Upon this he drew fine lines, first in red, next in green, and next in violet. Now, although these lines seemed to be close together, they were not so close as to exclude all light. Then the negative is placed behind this three-coloured screen, and the

picture, when transmitted on to a sheet by means of a lantern, shows all the softness of natural colouring.

At the present time the two processes of colour photography upon which the greatest hopes are centred are those invented by Dufay and Lumière. Dufay's is known as the dioptichrome method, and differs from Joly's in that his screen is made of a number of tiny coloured squares. The method of Lumière, on the other hand, employs neither lines nor squares, but the screen is covered with grains of starch, dyed blue, red, and yellowish-green. This is called the autochrome method.

None of these methods quite supplies the need of a colour process, experienced by every photographer. All that can be produced at present is one positive on glass, and what the whole world wants is a negative from which innumerable prints on paper can be made. Then indeed will the water-colour sketcher pack up her paints and withdraw in haste.

But in other directions photographic invention has prospered wonderfully, for the great and lasting benefit of mankind. Who can gauge the effects that have followed, and have still to follow, the photographing of the infinitely little and the infinitely big and distant? The camera harnessed to the microscope has been of incalculable help to the bacteriologist and the biologist; the camera harnessed to the telescope has been of equal value to the astronomer. It has enabled him to measure the height of the mountains of the moon; to examine more intimately than would

otherwise be possible the spectra of the heavenly bodies, so that he can tell us which of the elements of our earth exist in the sun and the other stars and the nebulæ, and which of the stars are racing towards us through space and which of them receding from us. And most romantic thought of all, perhaps, his camera has discovered stars that are quite invisible to the eye, even when aided by the most powerful telescopes. Some of these stars that have been photographed are so infinitely distant from us that it is computed that the light which affects the photographic plate must have left its source tens of thousands of years ago. And light, remember, is travelling at the gentle pace of some 180,000 miles a *second.*

Probably the most popular development of photography is the one which gives us the "movies". No part of the civilized world is without its picture palaces, and every day millions of people—rich and poor, men, women, and children—sitting in darkened halls give support to a vast ramification of allied industries founded on a camera, so to speak. The moving-picture business is one of the great romances of modern invention. Twenty-three years ago, in the early hours of a spring morning, some London policemen beheld the first moving pictures ever thrown upon a screen. They were on point duty in Hatton Garden—which is not a garden, but a very dull and dingy street, given over to diamond merchants and watchmakers—when they heard cries and shouts coming from the workshop of a Mr. Robert

Paul. Shouts and cries at three o'clock in the morning seemed to those Hatton Garden policemen to be matter for investigation; but they turned out to be symptoms, not of danger or alarm, but of joy. There were no burglars at Mr. Paul's workshop, but a jubilant Mr. Paul and his assistants. They had just succeeded in passing a moving picture, forty feet long, through a projecting lantern. And the policemen waited while it was put through again, for their benefit; so you see that even a policeman has a stroke of luck sometimes.

Mr. Robert Paul is the father of the "movies". It was his invention in the first place, and very many of the subsequent improvements—nearly all of them, in fact—originated with him. In France the Messrs. Lumière produced the *cinematograph*. The word has now worked its way into common usage, and is applied indiscriminately to any living-picture entertainment, though strictly it is the name of a particular type of projector. Both Paul and Messrs. Lumière, though they worked independently and along totally different lines, arrived at very similar results. Edison's kinetoscope, a rather crude "peep-hole" contrivance that attracted a good deal of attention at the Chicago World's Fair, in 1893, was the starting-point from which they worked. One put a coin in the kinetoscope and so started an electric motor, which gave motion to an endless band of film on which were printed a succession of photographs. One saw these pictures through a small lens. They were illuminated

X RAY PHOTOGRAPH OF A FRACTURED LEG

The bullet which caused the fracture appears on the right The photograph was lent by Dr Lyster of the Middlesex Hospital

Cap IX

by an electric lamp, and a rotating shutter gave them to the eye one by one in rapid succession, so that the illusion of real motion was obtained. The word illusion is used advisedly. When you go to a picture theatre you do not see actual movement, though you believe you do. What you really see is a very great number of snapshots of people and animals in motion. These snapshots are thrown on to the screen at the rate (approximately) of sixteen a second. Each picture remains on the screen for (approximately again) $\frac{1}{32}$ of a second. Obviously there is an equal period when you see nothing at all. For $\frac{1}{32}$ of a second the shutter obscures all the light from the camera while the next picture is coming into position to be shown. The illusion of motion is due to a phenomenon known as *persistence of vision*, which means that the brain retains an image telegraphed to it by the eye for some little time after the eye has ceased to see it. We are not conscious of the gaps between the pictures on the screen, because during the time when our eyes are dutifully looking at nothing our brains are still occupied with the last picture seen.

In Edison's kinetoscope the film had a continuous motion; so had the early screen pictures. But modern films have an intermittent motion. As the camera-man turns his handle, the unexposed film unwinds from its spool, forms a deep loop in the front of the camera, and passes into the clutches of a "gate", a contrivance that jerks it into position behind the

lens for exposure sixteen times a second. Now that so many of us are amateur cinematographers with our own cameras and printing machines—our entire outfits possibly have not cost us more than £20—it is perhaps superfluous to enlarge on the processes of motion-picture making. So I will merely mention here that the process required to expose the negative film in the camera is repeated almost exactly to expose the positive film in the projecting lantern, and thus to give to the tiny pictures on the ribbon of film—each is only 1 inch by ¾ inch—the semblance of life, life-size. It is all very wonderful and ingenious, this business of taking and making the movies. Chemists, scientists, electricians, opticians, mathematical-instrument makers, engineers, the celluloid-film people—a great procession of wise men, each giving his quota—have passed along the photographic road since old Daguerre exposed his silver plates for several hours. The Marey Institute in Paris has given us almost incredible photographs of high-speed motion; the bullets' flight and the flight of insects, whose motions our eyes are far too slow to see. Doctors can watch in living pictures bacteria at work in our blood; Carvallo has taken X-ray motion-pictures of the functions of digestion; and it is not uncommon for physicians to take continuous photographic records of their patients' hearts and pulses. The least we can say of the latest developments of photography is that they open the gates upon the most alluring fields of scientific investigation.

CHAPTER X

Machines that Feed Us

One may reasonably feel inclined to resent the idea of being fed by machinery. One thinks instinctively of *pâté de foie gras*, and the ramrod apparatus with which the unfortunate goose is stuffed, or else of hunger strikers and forcible feeding. Yet when one stops to consider, there is little modern food which is not machine-made—partially, if not wholly. Even the home-grown egg produced by the unenterprising farmer is laid by a hen fed at least on steam-thrashed grain, if no other machine has had a share in her nutriment. In fact, so intricate and varied are the machines used in feeding the multitude that we can hope to mention only a fraction of them. There are many great industries devoted to the production of liquors and drinks of different kinds, many to the making of condiments, and many more to the preparation of actual food-stuffs. Old-fashioned folk speak disparagingly of "machine-made trash", but there can be no two opinions upon the superiority, hygienically speaking, of food-stuffs that are touched only by scrupulously polished machines and those that are touched by questionable hands. Bread, jams, butter,

and pickles made at home under ideal conditions cannot be improved upon, but the same articles made in small premises in unhealthy surroundings, by work-people in dubious raiment and having an imperfect notion of the uses of soap and water, cannot be regarded as beyond reproach. The large factory, with its acres of floor-space and its perfect ventilation and its omnipotent machinery, is admirable as a kitchen. Adulteration of the materials used may exist—there is no denying that it does exist—but at any rate there is no unwholesome contamination.

There is no question that bread is the most important article of food in most parts of the world, and the strange thing is that the dearer it is the more people eat of it, because they have less money to spend on meat. As we have seen already, the stick to make a furrow in which to grow corn, and the hand-mill in which to grind the ripened ears, were amongst the earliest appliances used by man, or rather woman. The scratching stick soon developed into a plough, and the plough into a steam plough, besides which there are numbers of other complicated machines which are necessary to the large farmer who wants to make the utmost out of his land.

In Great Britain we sometimes see steam ploughs, but the great stretches of country in what we may call the "new" parts of the world could never have been cultivated profitably without the help of steam. In Great Britain we consider a twenty-acre field something very large and unusual, but in Canada, or

Australia, or Africa, a field of twenty square miles is no rarity. The old methods of ploughing with horses or oxen would be hopeless on farms of such colossal dimensions. The work would never be finished, and great numbers of beasts would have to be supported, since the strongest muscles tire and the most willing heart will fail unless it rests at stated intervals. To deal with such immense tracts of land a great many ingenious machines have been devised.

Possibly in the first instance the virgin ground with its rocks, roots, tree stumps, and other undesirable contents is riddled with dynamite cartridges which are fired simultaneously. The surface and subsoil are thus broken up, while the mysterious living forces which make the ground fertile are gently stimulated. Then a huge plough adapted to the particular kind of soil comes upon the scene. It may be a plough for turning over heavy soil, or one for breaking up the matted sods of heath land, or a "knifer" which cuts out roots and rocks with perfect ease. Stationary steam-engines work at opposite sides of the fields, with a cable passing between them, up and down which the plough travels.

The harrow and the roller follow—there are, in fact, uncanny machines which perform all three operations at once at the bidding of a huge traction engine. There are machines for eradicating noxious weeds, such as couch-grass, machines for ridging fields for such crops as potatoes, machines for cutting drains below the surface, machines for sowing seeds or plant-

ing tubers—machines, in fact, for every possible contingency.

Latterly we have heard a good deal of the "agrimotor"—the petrol or paraffin tractor applied to agricultural uses. The necessity for breaking up grass land for cereals led to the creation of a special Government department dealing with agricultural machinery, under whose ægis the agrimotor has been specially encouraged. The agricultural tractor for field operations is undoubtedly cheap and handy in use, but the English farmer has been unjustly blamed for his suspicious attitude towards it. He is, as a matter of fact, showing common sense rather than the "pig-headed conservatism" of which he is accused; for in our hurry we have had to send to America for the tractors. And the American conditions of agriculture are very different from ours, and their machines are not easily adaptable.

A clergyman named Rham is credited with the invention in 1841 of the drill for seed-sowing. Prior to that time drills had been made by the dibble and the seed sown by hand, but the mechanical drill lightened the work and shortened the time required for the operation to an extraordinary degree. After sowing, the growing plant has to be cared for by hand, since there is yet no machine sensitive enough to differentiate between wheat and tares, until the harvesting time comes round.

Even in Great Britain the mechanical reaper and binder has come into general use. In country districts

you may sometimes see men cutting grass with a scythe, in a field that is too small to need a cutting machine, but the sickle is a tool which must be nearly obsolete. There are many large fields in Great Britain, but try to imagine the labour involved in harvesting on a typical Canadian farm of, say, ten thousand acres! Armies of labourers arrive at all the farms in Canada at harvest time, and there they work for two or three weeks, aided by the wonderful machines which make this stupendous farming possible. The usual division of labour is as follows: One machine, worked by three men, reaps two hundred and fifty acres. When all the corn is thoroughly dry the stooks are gathered and thrashed, the grain is sent to the mill, and the straw is burnt. On the small farms of Britain and many other countries the straw is of value, and we see the elevators at work building up ricks of unthrashed corn. The thrashing machine goes round upon a regular tour, all the farmers of a district using it in turn. A weird operation it is when seen by the imperfect light of stable lanterns on an autumn evening — the huge puffing machine, the indeterminate bundles of corn falling into the hopper, the clouds of steam, the buildings looming dimly in the background, the distorted shadows of people passing in front of a lamp—it might well be a scene from the past, a reconstruction of mystic rites and sacrifices offered to an impatient god.

The following picture of Canadian wheat-fields is taken from Sir John Foster Fraser's *Canada As It Is*:—

"Now to the wheat-fields that seem to have no end. On a knoll we pull up the horses. Like great ochre-dyed carpets the wheat spreads itself out. The day is warm with the fragrant warmth of ripe vegetation. Yet there is a ping, a tartness, a something in the air that spurs the blood and prevents any trace of drowsy sensuousness. The day is cloudless, the sky real blue with no fleck of white in it. Distant objects, though reduced, are clear with crisp tangibility. Far off can be seen the log-hut of a settler. The man is out with his self-binder and two horses. Down goes the wheat, it is cut; it is gulped by the machine, an armful is automatically bound, and when the steel arms hold half a dozen sheaves they are thrown out. A boy lifts and stooks them. The reaper is two miles away, but we hear its whirl; even the sharp complaint of the man to the horses can be heard.

"We of England, with our farmsteads, our hedge-rows, and eight- or ten-acre fields, cannot quickly realize the top of the world as it looks, robed in wheat, where the wheat patches are fifty, a hundred, five hundred acres without a break; then merely the width of a cart-track before there begins a sea of full oats rustling like tissue-paper; then more wheat, and on like this, till the eye can follow no farther—where there are no hedges, and the homesteads are rough stacks of log and the stables of turf.

"That is the scene through hundreds of miles of the wheat belt in Canada. The immensity of it impresses you. Then comes a weary feeling at the

sameness of it all—the rough huts, the boundless, unvarying seas of wheat, on and on, and still on.

"After that comes the wonder, and this is abiding. Ten years ago, six years, three years, maybe only two years ago, the land over which your eye sends a wide pupil was prairie, where no *man* had ever trodden."

The corn being cut and thrashed, it is carried to the mill. Flour mills worked upon modern principles are very different places from the picturesque windmills or water-mills of yesterday. In fact, the mill of the countryside has almost disappeared. Travelling dealers buy up all the available grain and send it by the help of a motor or steam-tractor to some city mill —a den of roaring, shrieking, grinding noise. The steam-driven mill-wheels crush the grain, and the flour is graded and bagged with astonishing rapidity. At the large bakeries, again, machines are used wherever possible to save time and labour. Bread-making is an arduous business at best, involving the baker in broken nights and hours of hard work in an uncomfortably hot atmosphere. The introduction of steam-heated ovens and other labour-saving devices is a boon to the baker no less than to the consumer.

Now let us think about the product which goes with bread naturally—which, in fact, ought to have been put first in point of importance, since a large number of persons depend upon it entirely for their subsistence. The day of the old-fashioned dairyman is fast approaching its close, and he will soon sink

into utter oblivion. The sooner he sinks the better for the world. Legislation and machinery, actuated by common sense and the medical profession, have put an end to his career. Even under the best conditions the old methods of milking and dairy work were risky, and under bad conditions they were positively pestilential. To-day the law with regard to milk supply is stringent, and since large numbers of men would be necessary upon a large dairy farm, if all the regulations are to be complied with, the ever-ready machine comes to the farmer's help.

Think a moment about the ordinary country dairy, now happily rare and daily becoming rarer. The cows come in from the pasture and take their places in the stalls. Their udders are washed, and Jack or Bill, after washing his hands and putting on a clean coat—*perhaps*—takes his seat upon the stool and causes the milk to flow into a bucket, which has been previously scalded with boiling water by the women of the house. When full, the contents of the bucket are emptied into the cream-pans, which also have been scalded, and the milk is allowed to stand all night. To all appearances the dairy is nice and clean, but it is probably old and rough-walled—there will be many chinks and crannies which may harbour undesirable guests—and quite possibly the window faces the farm-yard. Remember that this is a description of the dairy work upon a well-conducted farm of the old style. The dairy of a bad farm is a veritable chamber of horrors.

Well, all this is being changed. No longer do

Jack and Bill settle themselves for a quiet milk in the cool of the evening. Their place is taken by a machine with nozzles and pipes which, by means of a vacuum pump, milks two cows at once. Not only does this machine do three men's work, but the milk passes without exposure into a sealed can, and thus is spared the dirt inseparable from the cleanest of hand-milking. After being strained through sterilized cloths the milk is put into a refrigerator and cooled to a temperature of 40 degrees. This is to delay the souring of the milk by its own natural germs, which may begin to multiply at a temperature of 59° F. Milk that has been properly cooled, and is contained in properly sterilized churns, may be sent long distances by night trains without turning sour. But supposing it is only required for local delivery, the ideal plan is for the milk to flow automatically from the refrigerator to the bottle-filling machine. The sterilized bottles—or, better still, paper bottles—are filled from the machine without allowing the milk to come into contact with the air at all, and in this way it can be taken to the customer's door with a minimum of risk.

Milk, as milk, however, is not the only product of the dairy. Cream, butter, and cheese are all important articles of food, and articles which may become dangerous unless they are prepared with the greatest care. No longer is cream skimmed from the top of the milk. A machine separator does the work, and retains any dirt that still may be left in the milk.

Machines churn the cream and work the butter, all with the least possible exposure of the material. Other machines clean all utensils and machines after each operation with steam. Nothing is left to chance. The scalding steam penetrates every part of every pan and tube, and entirely obviates the possibility of dirty vessels.

It is purely by enterprise and strict attention to detail in the matter of dairy work that Denmark now occupies her present position in the commercial world. Denmark led us all in the matter of hygienic dairy work. She was the first country to make extensive use of machines for this special branch of industry, and while other countries wasted their skim milk or turned it into size she gave it to her pigs, and so rose supreme as a bacon producer. So successful are the Danes as dairymen that the practice of sterilizing or pasteurizing milk which is growing in favour in most countries is very little practised in Denmark. By milking clean cows under clean conditions, and using a pail having a double bottom enclosing ice, the milk can be delivered safely without the need of any other process.

Cheese-making, if not quite as old as the hills, is certainly a very ancient industry, and one that was carried on, as originally invented, for countless centuries before any improvements in the method were considered necessary. Scientific cheese-making is really quite a modern affair, and owes its existence to the researches of chemists. It is only since the

study of bacteria attained prominence that the processes undergone by milk during cheese-making have been understood properly. The labour-saving genius has also turned his attention to cheese, with the result that easily-handled machines now do the work of the cumbersome presses of olden days. Unfortunately a cheese and butter factory is not an entirely delightful place to visit. In appearance it is most attractive, whether we inspect the sterilizing apparatus, the separating machines, the steam-driven churns and workers, the great vats of milk and whey, the tanks in which the curd is cut up by mechanical knives, the rows and rows of shining presses, or the drying-room where the finished cheeses stand in their serried ranks waiting for time to finish them. But we want to hurry through our inspection as fast as we can, and that is because of the terrible smell. We may admire the method and order of the factories, but we like to do so from a distance.

It is rather a difficult matter to say positively what article of diet comes next in importance to bread and milk, but we shall not be very far wrong if we now pass on to sugar. Sugar is a very valuable food in itself, and we require large quantities of it for cooking and for preserving fruits. Sugar-growing is a branch of agriculture which does not depend much upon the machine. The land must first be prepared by machine, of course, but when the steam-plough, harrow, and roller have done their work, and the earth has been ground into powder, human labour must attend to

the business of planting, weeding, and cutting. The sugar-refinery, however, is an abode of highly-complicated machines, which do all the work formerly done by the hand-mill in a very much more efficient manner and in a fraction of the time. The hand-mill is still largely used in India, which accounts for the fact that the Indian sugar industry is rapidly dying out. Human labour, cheap though it may be in some parts of the world, can never compete with the machine.

The sugar-cane is a convenient and profitable thing to deal with, for none of it need be wasted. While it is growing the leaves have to be cut off, and these are not thrown away, but are used as manure or as fuel. When the canes are cut they are tied into bundles and taken to the mill, where they are placed on an endless band and carried off to destruction. Soon they reach the rollers. An excessively busy roller crushes them down upon an under one, and then, as they struggle out, catches them again and crushes them upon a second one. Mangled and torn, and deprived of all their precious juice, the canes sink miserably upon another endless band, which takes them off straight away to the furnaces. Having been utterly ruined, they feed the engines which ruin their fellow-canes.

In the meantime the juice is collected, strained, and heated to a point high enough to stop fermentation, and then falls into a copper known as the defecator. Here it is brought nearly to boiling-point by steam

from the engine—all the boiling in an up-to-date refinery is done by steam from the engine—so the scum rises to the top and the dregs sink to the bottom. Then a plug situated a little below the middle of the defecator is opened and the clear syrup runs out, leaving the scum and the dregs to mingle together and be subjected to further washing and steaming.

After leaving the defecator the juice goes to the eliminator, where it is freed from more of its impurities. Then it has to be boiled to make it crystallize, and the crystallizing process is very ingenious. Three or four sets of boilers are used. A separate furnace for each would be very costly, so that difficulty is overcome in the following manner: The first boiler is heated by steam from the engines, and the vapour from the boiling juice in the first boiler heats the juice in the second, and so on.

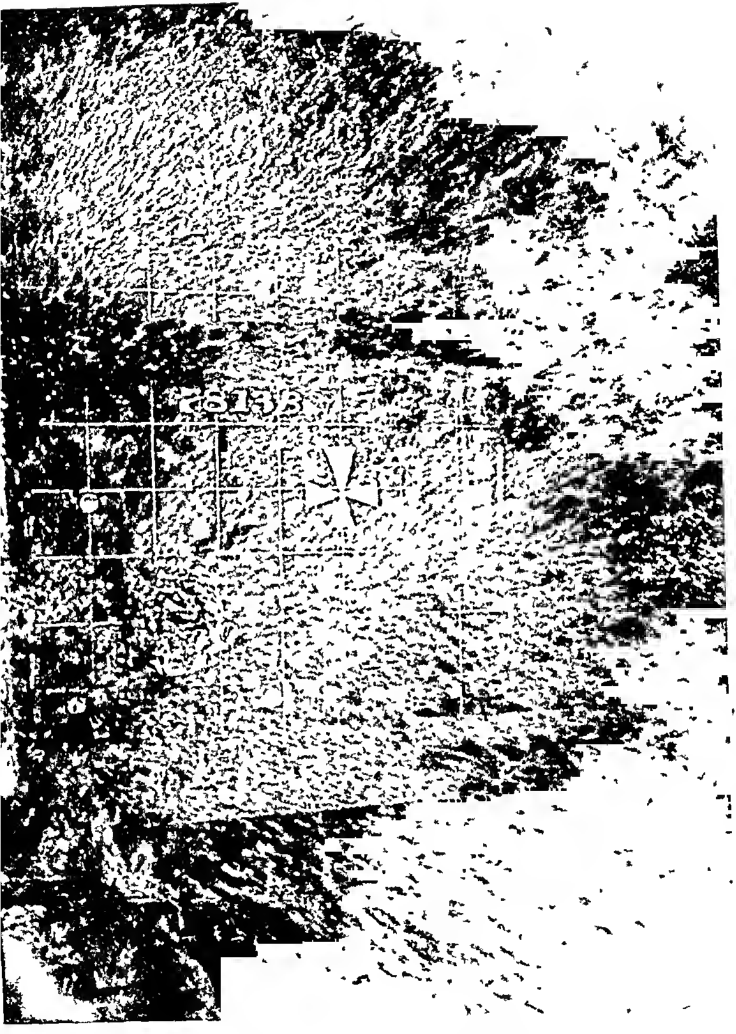
We must not spend too much time over sugar, so only bare mention can be made of the final processes of separating the sugar crystals from the molasses, the machines for whitening and moulding the sugar and for cutting it. We must now pass on quickly to the jam factory, and glance at the wonderful machines there—machines which can make jam and bottle it much more cheaply than you can make it yourself.

Many of the most up-to-date jam factories are situated in the middle of their own fruit farms, and thus the fruit can be picked and carried immediately to the boiler without any long journey to damage

and impoverish it. All the boiling is done in steam-jacketed, silver-plated vessels, and from the moment the fruit enters the boiler it loses all connection with the outer world. Nothing more is done to it by hand until it finally appears upon the tea-table, when some of it will probably come into contact with somebody's fingers, good manners notwithstanding.

I dare say you have assisted at jam-making festivals at your own home, and in that case you will know what a tedious, anxious business it is. The sugar wants to stick to the pan and burn, the fruit wants to boil too fast, and the whole process means three or four hours of ceaseless care for somebody. But in the jam factory the fruit and sugar are tumbled into the boiler together and left to themselves for three minutes, at the end of which time a tap in the boiler is turned on and out rushes the completed jam. It pours away in troughs provided for it, cooling rapidly all the time. When it is sufficiently cool it arrives at the bottling department. Exactly the right quantity flows into each jar, a paper top is dropped on it, and all that remains to be done is the sealing and labelling. Truly this is a great improvement upon the old methods. Pickling and fruit preserving are carried out in a similar way, with a minimum of contact with the hand.

Preserving fruit by means of heat — of sun-heat, that is to say—is a custom of great antiquity. In hot countries dried fruit, such as raisins and dates, seems to form the staple food of wandering tribes. It is



A REMARKABLE PHOTOGRAPH

This photograph, believed to be the first of its kind, was taken at the instant of impact of a 9.2 inch shell on an armour plate. White hot, highly incandescent particles of steel dust and fragments fly in all directions. The muzzle velocity of the gun was 2347 foot seconds. The photograph, by J. I. Gould, is reproduced by permission of Armstrong, Whitworth, & Co.

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light and easy to carry, and has an extraordinarily high nutritive value. But it must be sun-dried. There is still a fortune awaiting the inventor who can devise some artificial means of drying such high-class articles as Bordeaux plums, which seem to lose all their distinctive flavour when dried by stove heat. Sun-dried meat is another staple which may be regarded as one of the earliest of food-stuffs. Fire-making man added a taste of smoke and dried his meat in comfort at seasons when Nature refused to do it for him. Fish lends itself to the same process with very good results. Dried fish and meat, however, lose much of their flavour and attractiveness, and in populous countries people have lost their taste for pemmican and salted fish. Bacon and haddocks, or herrings cured in different ways, are held in high esteem, but they are not ideal foods. But in Great Britain we do not raise enough live stock for our butchers and fishmongers, and the inventor has had to come to their assistance.

Nicholas Appert was the first man to make tinned meat, and he did not tin it, because in his day there were no cheap tins. He bottled it in glass or china jars. He did not understand what it was that he had done, but he found that meat that was cooked and then placed in air-tight vessels would keep good for a very long time. Napoleon, whose dictum it was that an army fights on its stomach, realized the importance of this discovery, and gave Appert a handsome reward, but nothing was done with the idea at that stage because of the difficulty and expense of provid-

ing an army on the march with food in china jars. It was not until America produced the cheap tin that Appert's invention became of popular use.

Tinned meat is now so widely-spread an article of food that the misconceptions still surrounding its manufacture are extraordinary. Many persons who are otherwise well-informed persist in regarding tinned meat as the one and only source of ptomaine poisoning, without reflecting that ptomaine germs are all around us in the air, and may settle on anything we eat, whether it be a slice of bread, an apple, or an acid drop. Without a doubt stale meat is a favourable breeding ground for the creatures, but meat tinned by a reputable firm is as fresh as can be. It is simply cut up into pieces of a suitable size and put into the tin. The lid is then soldered down and a vent-hole made for the escape of steam during cooking, just as your mother makes a hole in the crust of a meat pie. The tins are placed in a boiler and the steam turned on, and in a few minutes the cooking is completed. The vent-hole is soldered over, a coloured label put on the tin, and nothing more needs to be done before the tin is put upon the market.

Fish that is intended for tinning needs to be treated very carefully and very quickly, as the process of decay in fish is more rapid than in meat. It is first washed in water at a temperature slightly above freezing, just sufficiently above, in fact, to be water and not ice. The fish is prepared for cooking and then washed again before the pieces are put into the tin.

After the boiling the steam issuing from the vent-holes of the tins is tested to see if the cooking has proceeded far enough. When the fish is proved to be "done" the vent-hole is soldered down.

Tinning is a wonderfully convenient process for the preservation of perishable foods of all kinds in small quantities, but it is of no use for dealing with food-stuffs in bulk. Yet in Great Britain we import yearly thousands of tons of fruit, meat, poultry, game, and farm produce, while to many of our tropical colonies we export home-grown meat and vegetables. Obviously it would be awkward to tin a whole bullock, even if people would be content with boiled beef. The popular taste, however, demands roasted meats cut from a joint, and here the tin fails. The machine which takes its place is the refrigerator.

The principle of the refrigerating machine is quite easy to understand when we appreciate one scientific fact: that when a solid expands into a liquid it has the power of absorbing heat from surrounding objects. The same thing happens when a liquid expands into a gas, and thus we can speak of generating cold by heat, which sounds a contradictory statement. Nevertheless this scientific principle can be made to work for man only by the help of intricate machinery. The ice-machine, which you can make at home, is simplicity itself—a bucket, a jam-jar, a few pennyworth of ice, and a handful of salt, and there you are. But you have to do the work yourself, and making the ice revolve round the jam-jar on a hot day when you are

dying for the ices is a back-aching job. The great cold-storage tanks of the modern liner and the freezing rooms in which the refrigerating process is carried on require a machine-made temperature which can be regulated, and the machines which can provide this are very costly and complicated.

There are three different kinds of freezing machines in general use to-day, the difference lying in the gas used for the production of cold. One type of machine compresses ordinary air, another carbonic acid gas, and the third, and most popular, ammonia gas. As you know, when a gas is compressed it liquefies. The liquid gas is forced through coils of pipes where it returns to its gaseous form, and at the same time absorbs heat from its surroundings.

There are nowadays innumerable industries which call in the aid of freezing machines, but we must confine ourselves here to those which take some part in feeding the multitude. In brewing and mineral-water making, in tea factories, and sugar refineries, and chocolate factories, we find refrigerators installed as part of the essential equipment, while hardly less important than the freezers and cold-storage rooms which make possible the importation of foreign foodstuffs are the installations which keep perishable food fresh and sweet in shops. All well-established dairies, butchers, and fishmongers now have cold-storage rooms, and possibly it will not be very long before private houses have small refrigerating plants in the larders. The ice-house has been a feature of large

country houses for many a day; the next thing is to make the cool chamber a feature of small town houses.

The usefulness of the refrigerating plant lies of course in the constitution of the bacteria which cause decay. The decay of organic matter is a necessity of nature, and need not be regarded with any dismay now that we have means of combating it when necessary. These particular germs are rendered powerless when they are frozen. They are not killed, but they are effectually put to sleep and can do no harm. Thus a piece of frozen meat or a frozen cabbage will remain as fresh as it was at the moment of freezing until it is thawed. Mammoths have been found, from time to time, encased in blocks of ice, which have preserved them in exactly the same condition for centuries, and it is said that their flesh has been eaten at banquets. It must not be forgotten, however, that the decay microbes become active again immediately their host is thawed.

These, then, are a few of the ingenious machines which prepare our food-stuffs for us, but as yet we have made no allusion to the mightiest machine of all—the human brain. Supposing there were no mechanical agents for pounding, grinding, pressing, drying, or refining the various natural substances which we eat or make into drinks, there would still be a number of products for which we are indebted to the inventive instinct. Until the beginning of the nineteenth century very few additions were made to the tables of Great Britain. The Romans introduced

the arts of agriculture and fruit-growing—arts that were forgotten and reintroduced several times before they became firmly established in the country—sugar was first imported during the reign of Stephen, potatoes, rice, tea, coffee, and cocoa at different times. But the fruit of the best growers would be considered poor in size and quality according to modern standards; the milk supply was small, the yield of corn or roots to the acre was small, there were very few varieties of green vegetables, and, the feeding of animals being so little understood, the amount of meat produced was small in proportion to the head of live stock raised. There was nothing in the way of scientific farming. Farm produce, whether vegetable or animal, grew very much as it liked. Dairy produce would be plentiful at some seasons and unobtainable at others, owing to the fact that "the cows managed badly", as careless farmers still say to-day. Cocks and hens were allowed to pick up a livelihood for themselves, and the eggs were found or not, according to the zeal or want of it in the urchin told off for the purpose. There were no imported foods except spices and grains and a few articles of luxury, because there was no means of preserving perishable goods through a sea voyage.

Various causes combined to change this order of things. First, the increasing population demanded more and more food; next, the rise in wages caused a demand for greater variety; then the war brought high prices to the farmers, and made good farming

profitable, while improvements in travel created a taste for delicacies of all kinds. Lastly, the advances in science opened the eyes of enterprising chemists to the vast untrodden fields of research, and the study of bacteria was begun in earnest.

Nowadays the careful farmer understands every inch of his ground. He knows just what the soil of each field contains and what it lacks, and how to make good its deficiencies. He knows, too, exactly what crops to put in each field and which kind of each seed to buy. The seeds have been grown especially from selected stock—a farmer now knows the pedigrees of his seeds as well as those of his cattle—and he knows he may confidently expect good results from them. Moreover, the farmer of to-day can grow a far greater variety of crops than his predecessor of a hundred years ago. Clover was introduced into this country about the middle of the eighteenth century, but for some time it was regarded with suspicion. Different members of the *Brassica* family made their appearance at various times, and the cult of the *Leguminosæ*, for consumption by both man and beast, became important. Popular opinion with regard to many plants underwent a change, several which were formerly regarded as poisonous—for instance, the tomato—being found to be wholesome and appetizing. Fruit trees also came under notice, with the result that not only have the size and flavour of fruits been improved, but the trees have been made much more prolific. The pipless orange, which is so much larger

and more delicious than the ordinary kind, is a product of the patience and enterprise of the fruit breeder. Fruit culture has led to a side issue of another sort, for, to help his fruit-blossom to set, the fruit farmer keeps bees, and bee culture is now an industry of great and increasing importance.

The milch cow may be almost regarded as one of man's inventions. The wild cow has milk for a short time while she is suckling her calf, but the domestic cow is expected to yield generously for the greater part of the year. This apparent miracle has been wrought by centuries of care, but modern study of selective breeding has had better results than all the care of the unenlightened years. Whereas horse-breeding has always been a matter of importance, cow-breeding was thought little of so long as beer was the common drink. The bacteria which are responsible for butter and cheese are now thoroughly well understood, while the various processes of condensation and evaporation make it possible to preserve milk indefinitely. At the present time a Polar expedition can keep itself supplied with milk for years if need be, whereas in days gone by the cottager with a cow in his meadow might not have a drop of milk for months.

The most noteworthy point, however, about modern agricultural improvements is that they all tend to reduce waste. The old-style farmer is the most wasteful unit in the world's scheme of economy, and he must be educated out of existence. The scientist

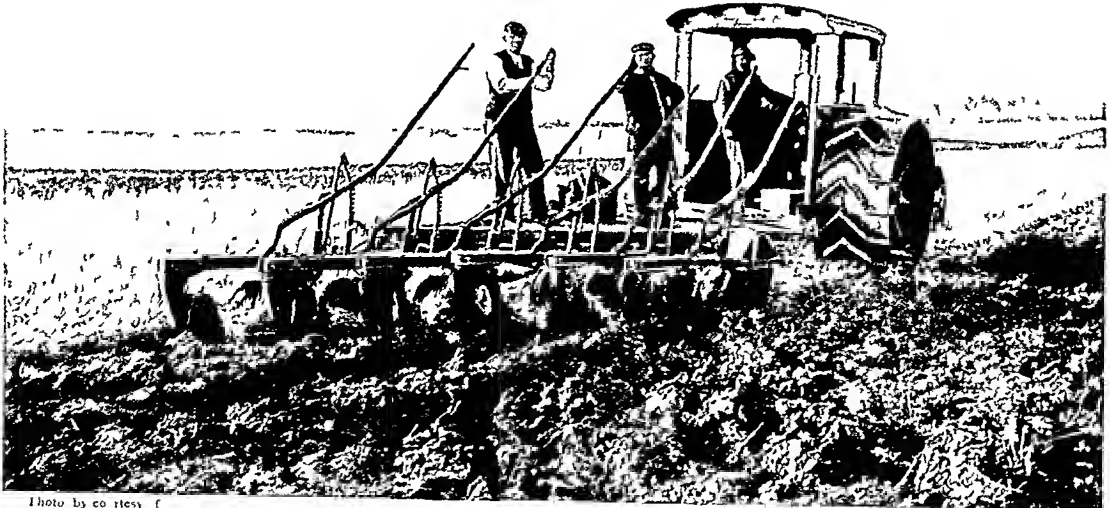

Photo by courtesy of the Canadian Government Emigration Department

MOTOR PLOUGHING IN MANITOBA, CANADA

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comes to his help in numbers of ways, but principally does he help with the treatment of the land. Farm-yard and stable manure is excellent stuff, but it is expensive, and does not always provide a hungry field with just what it wants. The scientist, in his effort to find a use for everything, has discovered that many waste products of industries of all kinds may be utilized to enrich the soil. Basic slag, which comes from the steel-works, and sulphate of ammonia, a by-product of the gas-works, are two of the most important artificial fertilizers of to-day, while such things as bones, dried blood, horns and hoofs, and shoddy, which are collected from a variety of trades, are all made use of in the same way. The scientist has also proved to the world the value as fertilizers of certain natural substances—the nitrate deposits of Chile, the muriates of Germany, and the guano of Peru and of numerous islands in the Southern hemisphere. More than this, the scientist has shown how the bacteria of the soil can be gently stimulated by a discharge of dynamite and the growing plants encouraged by mild electric shocks. The engineer, by his wonderful irrigation schemes, can make the desert blossom and bring forth fruit; the scientist, it seems, can perform the same miracle for the barren rock.

CHAPTER XI

Machines that Clothe Us

Ostensibly, the clothes we wear are made of one, or a mixture of two, of four materials—namely, wool, linen, cotton, and silk. Wool is the oldest of these materials, although among Eastern nations silk probably was used almost as early. Linen also has been known to man for a very long time, but cotton is a recent addition to our commodities. As has already been mentioned, spinning and weaving are amongst the oldest crafts, but in this chapter we want to consider them, not in the light of crafts at all, but as huge roaring industries employing millions of workers all the year round.

If you are ever bold enough to enter a shop devoted to the needs of ladies, you will see at the "lace counter" dozens of boxes containing hundreds of yards of embroideries and laces, dozens of boxes containing hundreds of embroidered collars and other fal-lals. You will see enough lace and embroidery to bedeck half the ladies in London just in one shop. Your grandmother, dear soul, in her youth would spend a year in embroidering one flounce, and wear

it for the rest of her life. Your sister buys a machine-made flounce, much prettier than the one over which grandmamma took such infinite pains, for some ridiculously small price, ending, you may be sure, in "three". Whereas your great-great-great-great-grandmother spent all the winter spinning wool for the weaver to work up into a piece of broadcloth for her husband's best suit—which, by the way, would be expected to last him at least ten years—your father orders two or three suits in a season from a tailor, who makes them in a week, of cloth which was perhaps half an hour or less in the making. It is the machine which has brought about this enormous change in conditions—the machine which, at its inception, was received with howls of execration and abuse, was battered and broken, was accused of taking the poor man's bread out of his mouth, and regarded as the enemy of the country. If those same poor men could have looked into the future and have seen the prosperity of the mill-hands, the lads and lassies of Lancashire and Yorkshire, with money in the bank and warm, cheap clothes upon their backs, they would rather have fallen down and worshipped the machine as the benefactor of all mankind.

At the beginning of the eighteenth century appliances for spinning and weaving were very little improved upon those of two hundred years before. Both crafts were practised mainly by individual cottagers with the help of the spinning-wheel and hand-loom. Cotton goods were not made at all, because there was

no means of spinning a cotton thread strong enough for a warp. All fabrics were very dear and, according to modern views, very coarse and heavy; but, on the other hand, they did not wear out. Linens were all bleached by natural processes—that is to say, they were left out in the open for six months, a method which injured the fabric far less than the rapid bleaching by chemicals in vogue to-day.

It is worth noting that the earliest improvements in spinning machines were made in secret, with the idea of benefiting the inventor, not the industry. Thus it is more than likely that devices to accelerate the production of thread were made by people of whom we have no record. With the type of wheel commonly in use, however industrious she might be, the spinster could only turn out so many yards of thread in an hour. We have a picture of James Hargreaves, a mechanic employed at a cotton mill in Blackburn owned by the grandfather of Sir Robert Peel. Hargreaves, hanging about the house waiting for the thread his wife was spinning—impatient, no doubt, and fretful at the waste of time—with one of the clumsy, ill-considered movements men make in such a mood, knocked over the spinning-wheel. Here was a catastrophe! The wheel, by its own momentum, went on moving round and round, hopelessly entangling the thread, while Mrs. Hargreaves gave herself up to shrill scoldings, and the author of the mischief stared stupidly, open-mouthed, at the havoc he had made. He was not feeling stupid, however.

As he watched the wheel and spindle revolving on the floor, the idea came to him that a number of spindles might equally well be revolved by one wheel, and a number of threads be spun simultaneously. Checking the torrent of abuse hurled at him by his wife—or, perhaps, not even troubling to do that, who knows?—Hargreaves picked up the wheel and began at once to fiddle about with the spindle. In due course his machine was finished, and he found himself in the pleasant position of being able to do many times more work, and therefore to earn many times more money than his companions. Naturally such a state of affairs could not be kept hidden. The increased prosperity of the Hargreaves family was commented upon, we may be sure. Then Hargreaves made several "jennies", as he called his device, and sold them under promises of secrecy to friends. Then, of course, the secret was out, and the indignant spinners from the whole countryside, men who intended to protect one another and their own interests whatever happened, marched to Hargreaves's cottage and smashed everything smashable it contained, and then marched on to the Peel mill and smashed that.

How heroic these men must have felt when they performed these acts of violence, and how they must have plumed themselves upon their initiative and public spirit when Hargreaves, Peel, and some other manufacturers who favoured the introduction of machinery, all left the neighbourhood of Blackburn to prosecute their plans in other towns! Had they but

known it, these foolish people had only hindered their own advancement for a few years, and helped to build up prosperity for their neighbours. Hargreaves went to Nottingham, where, in company with one Thomas James, he started a factory for the building of spinning-jennies. His invention was stolen and copied by numerous manufacturers, but in spite of that Hargreaves prospered, and was said to be worth seven thousand pounds at his death.

A little way back it was said that true cotton manufacture did not exist in England because there was no means of spinning a cotton thread strong enough for the warp. The warp always had to be made of linen thread. This rendered the material costly and heavier than pure cotton, and put it out of the reach of all but the well-to-do.

It is strange to reflect upon the pranks of fortune. If anyone had asked a certain very poor man of Preston what he expected would be the future of his thirteenth child, born 23rd December, 1732, he would probably have sighed and told you despondingly that he did not know. He certainly would not have said: "My son Richard will die a knight worth half a million pounds." Yet that is what was in store for this poor, little, unwanted baby, whose parents did not know how to feed the children they had already. Life was a struggle hard enough, and the arrival of number thirteen, the unlucky number, made it harder still. But in this case number thirteen proved the lucky one.

Richard Arkwright grew up somehow, in the miraculous way in which the children of the very poor do manage to grow up. At a very early age, without having had any proper schooling, he became a barber by trade, and kept himself and helped to support his parents by cutting hair and shaving chins. Not a very elevating way of spending one's time, perhaps, but while Arkwright's hands were busy with his shears his thoughts were far away, dreaming dreams, working out ideas, scheming and devising. His brain was as nimble as his fingers, and it was not long before he found a more enterprising way of life. He invented a new method of dyeing hair and dressing it ready for the wig-makers. Hair prepared by his secret method was so good that a demand soon arose for it, and in order to supply the manufacturers he gave up his regular business as barber and took to travelling about the country, buying hair, making it up, and carrying it to the wig-makers.

In the course of his wanderings he came to the cotton-spinning districts of Lancashire and Cheshire. It did not take long for a man of his acumen to see that the spinning industry might well be in a better position. Now his thoughts had a new trend as he busied himself with the craft which earned his bread. How to devise some means by which cotton thread could be spun more rapidly and with better results than was possible by the existing methods? He went on with his dyeing and combing until one day, happening to be at a foundry, he watched a bar of red-hot

iron being drawn out between rollers. This set him to wonder if a thread could not be drawn out in the same way? By and by, with the help of a clockmaker named Kay, he set to work to make a machine which should fulfil the desired conditions, and, seeing success in front of him, he gave up his hirsute occupation for good.

His first machine was set up at Preston in 1767. It was proved later that a machine on a somewhat similar plan had been erected unsuccessfully at Birmingham in 1738, but Arkwright had never heard of this machine, so that his own is a genuine invention. His spinning-frame produced cotton thread of sufficient strength to be used as warp, which was quite an innovation in the cotton-weaving industry. But Lancashire would have none of Arkwright and his invention, and at last, being quite unable to make a living at Preston, Arkwright moved to Nottingham. Here he was fortunate enough to arouse the sympathy and interest of Jedidiah Strutt, famed for his improvement of the stocking-frame, who with his partner entered into business relations with Arkwright.

In spite of all his early troubles we must regard Arkwright as one of our fortunate inventors, as he rose to great wealth from the humblest beginnings and lived to see his inventions accepted by the manufacturers whom he had laboured to benefit.

A man whose work had as great an effect upon the spinning industry as Arkwright's, but whose story is

Photos Underwood

THE MANUFACTURE OF SUGAR FROM BEET AND CANE

The upper illustration shows the centrifugal machines where beet sugar crystals are separated from the syrup. Below, the cane sugar liquor, after hours of boiling in the vacuum pans, is seen pouring into the reheater, where paddles keep it from solidifying into sugar before it escapes it to the moulds

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less happy, was Samuel Crompton. He was the son of a Lancashire farmer, who occupied his spare time on wet days and in winter evenings with weaving. Samuel was trained in both occupations, and, his father dying quite young, he found himself at a very very early age in the position of breadwinner for the family. Fortunately his mother was a woman of stern character, who exerted herself to the utmost to give her children the best education the neighbourhood afforded. She was indefatigable with her spinning-wheel when she was not occupied with the duties of the house and farm, and the thread which she spun was woven into cloth by Samuel. Mrs. Crompton used one of Hargreaves's spinning-jennies, which, though it spun eight threads at a time, produced yarn of a poor quality. The threads were continually snapping and wasting the time of the weaver, besides injuring the cloth. No doubt all weavers used to find this propensity of the yarn most annoying, but they accepted it as one of life's little difficulties, unavoidable, and therefore to be borne with fortitude. But Crompton could not bear to be confronted with a difficulty which he could not overcome, and he applied himself to the problem of producing a thread which, although fine, should be strong.

His task was no easy one. The farm took up all his attention in the day-time, and it was necessary to weave all the evening. He made, moreover, a little money by playing the violin at gatherings and festivals in the neighbourhood. Even so the little family

could only just struggle along, and Crompton was unwilling to devote any time to a project which might prove wholly unprofitable. For five years he wrestled with his ideas, working far into the night when all his neighbours were sound asleep. Success came to him at last, and in 1779 he finished building a machine which could spin a wonderfully fine yarn. It was quite a simple contrivance, and one which anybody with a mechanical turn of mind could have copied. As soon as his fellow-weavers learned of the fineness of the yarn he was using, and the beautiful cloth he wove from it, they wanted to learn the secret. Since Crompton would not show them his machine they determined to see it for themselves, and resorted to all kinds of tricks in order to get into the house. Failing in these they brought ladders, up which they climbed and peered through the upper windows in the hope of seeing the wonderful tool. Irritated beyond measure by these proceedings, Crompton accepted the offer of a Bolton manufacturer, who promised that the trade would pay him generously for the secret. Crompton made known his device and was rewarded, not by the huge sums he had been led to expect, but by £67, 6*s*. 6*d*.! The manufacturer immediately began to build machines according to Crompton's plan, so that by the time Crompton had managed to save enough money to start a factory on his own account the supply of machines was already quite large enough to meet the demand.

The rest of his life was nothing but a succession of

disappointments, and in his later years he lived entirely upon an annuity of sixty-three pounds which some friends had subscribed to buy for him.

While these improvements in implements for spinning had been taking place, no attention whatever had been given to the craft of weaving and the loom. The loom in common use was practically the same at the end of the eighteenth century as it was at the end of the sixteenth. The only innovation was made in 1733, when a mechanic named Kay invented a "fly shuttle". Previously the weaver passed the shuttle from one hand to the other, but the fly shuttle travelled along on a little shelf, and so saved him the trouble. This device greatly accelerated the speed of the weaver, who began to demand more and more yarn, until, by the inventions we have just described, he had a plentiful supply. In fact, the supply was too lavish, and spinners who had adopted the new machines and could turn out large quantities of good yarn found the market overstocked. As a natural consequence the loom had to be improved, so that the weaver could use up the yarn as fast as it was spun. In this case again help did not come from the quarter from which it might have been expected. It was not a weaver who first made the power-loom, but a clergyman.

The Reverend Edmund Cartwright held a living in Leicestershire towards the close of the eighteenth century. His mind was progressive, and when working his glebe-land he introduced many improvements into

existing agricultural methods. His attention was attracted to the laborious occupation of weaving by a visit to Arkwright's spinning-mills in Derbyshire, and he determined to see whether he could not make a loom which should do the work more easily. The story is best told in his own words:—

"It struck me that as in plain weaving, according to the conception I then had of the business, there could be only three movements which were to follow each other in succession, there would be little difficulty in producing and repeating them. Full of these ideas, I immediately employed a carpenter and a smith to carry them into effect. As soon as the machine was finished I got a weaver to put in the warp, which was of such material as sailcloth is usually made of. To my great delight a piece of cloth, such as it was, was the produce. As I had never before turned my thoughts to anything mechanical, either in theory or practice, nor had ever seen a loom at work nor knew anything of its construction, you will readily suppose that my first loom must have been a most rude piece of machinery. The warp was placed perpendicularly, the reed fell with a force of at least half a hundred-weight, and the springs which threw the shuttle were strong enough to throw a Congreve rocket. In short, it required the strength of two powerful men to work the machine at a slow rate, and only for a short time. Conceiving in my great simplicity that I had accomplished all that was required, I then secured what I thought a most valuable property by a patent, 4th April,

1775. This being done, I condescended to see how other people wove, and you will guess my astonishment when I *compared their easy mode of operation* with mine. Availing myself, however, of what I then saw, I made a loom in its general principles nearly as they are now made, and it was not until the year 1787 that I completed my invention, when I took out my last weaving patent, August 1 of that year."

Since Cartwright's loom greatly facilitated the weaver's work, we may expect to hear that it met with great opposition. For a long time he could find no one to take it up, so he started a factory of his own at Doncaster. The expenses of the undertaking, however, were greater than he could bear, and workmen and neighbouring manufacturers alike combined to make his position unbearable. At length a millowner at Manchester was found willing to adopt the power-loom and set up four hundred of the machines; but scarcely had they begun to work before the whole place was burnt down. In spite of these rebuffs Cartwright did not allow himself to be down-hearted, but turned his attention to other things. A wool-combing machine and various other devices for assisting manufactures were the result, and he also spent a great deal of time with Robert Fulton, who was then experimenting with the steam-engine for use in ships. At length he met with a tangible reward in the shape of a grant of £10,000 from the Government.

About the same time was made another invention

which was necessary at that stage of the manufacture. We have seen that, after spinning machinery had been improved and the supply of thread increased, the looms were improved to use up the additional supply, and naturally more raw cotton was needed. The most tedious part of the raw-cotton industry was the separation by hand of the cotton from the seed. An American named Eli Whitney came to the rescue here, and produced a saw-gin which did the work automatically. His sufferings, however, were precisely the same as those of so many others of the inventors whose stories have just been told. His machines were broken by angry workpeople, while jealous manufacturers stole his secret before he had taken out a patent. Nevertheless, his gin ranks as one of the most important of the inventions bearing upon cotton; and though he did not make money by that, he made a fortune by the manufacture of fire-arms, an industry in which his inventive mind had full scope.

At the time of its invention the gin was made to operate over a stream of water. The seeds, which were regarded as waste products, fell into the water and were carried away. Science has proved to us since those times that the cotton seed is as valuable an asset commercially as the cotton itself, and the gin becomes incidentally a machine that feeds us. The extracted seed is put to a variety of uses. The husks are used as cattle-food and manure, while the crushed kernels are pressed into cakes which form the familiar

"oilcake" which is so helpful to the dairy farmer. The oil which is extracted from the seeds reaches our tables in many ways which we may not suspect. The "settlings" are used by soap-makers, and the refined oil is converted into butter substitutes, salad oil, and sardine oil. It is also used to make such commodities as medicines, ointments, the finer kinds of soaps, and oil for miners' lamps.

The manufacture of woollen goods is essentially the same as that of cotton or linen, but the preparation of the material for spinning involves certain differences. To begin at the very beginning, we find that there are now machines for actually shearing the sheep. On a large sheep-farm where there are thousands of animals the operation of shearing each one by hand would have to be performed by an army of men, but by the use of the machine each animal is shorn in a few seconds.

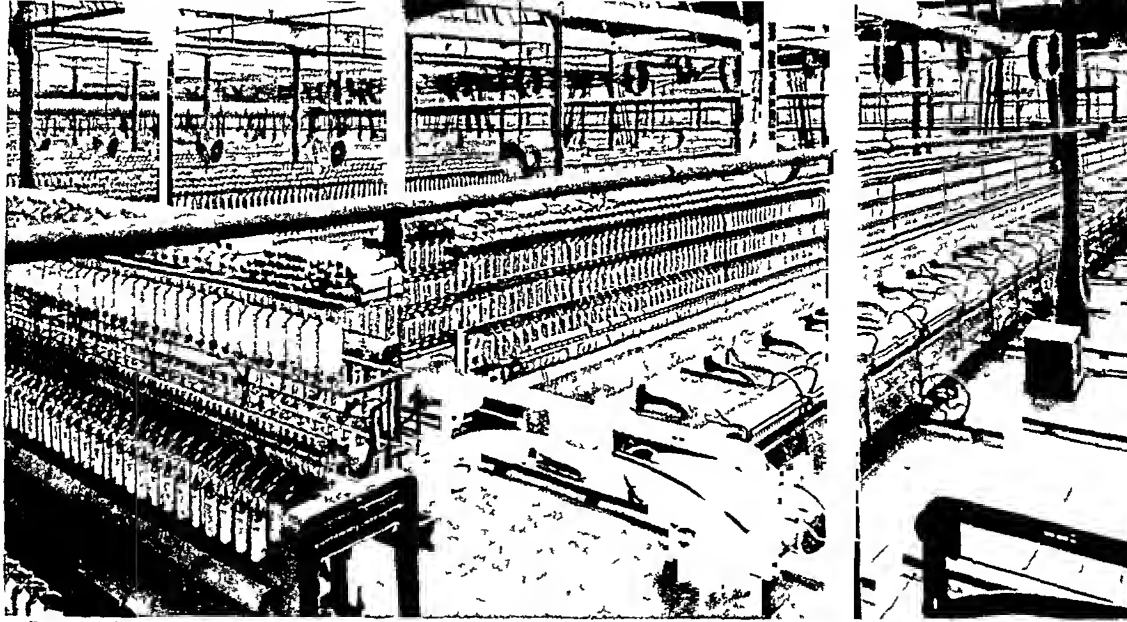
"Sorting" the fleeces is a long and tedious process, which has to be done by hand. Different kinds of wools grow on different parts of the sheep's body, while the breed and age of the sheep also affect the wool. The baskets of sorted wool are then taken to the cleaning machines. In its natural state the fleece is dirty and full of seeds and other foreign articles. It also contains a natural substance known as yolk, given off by the skin of the sheep, which is extracted, to be used as manure before the fleece is sold, by the enterprising farmer. Wool from the Argentine is full of a particularly troublesome kind of burr, which

sticks so closely that it cannot be pulled off by hand. A machine has been invented for extricating it, and the Argentine wool now has a place in the British market. Formerly it was sent to the Continent as being too poor in quality for British goods.

After it has been washed well, generally in five different waters, the wool is dried and taken to the "willey", where it is teased and the fibres loosened and opened out. Then it has to be oiled to render it soft and easy to work. By this time it is ready for treatment in any of the many ways in vogue, the nature of the cloth required determining the process.

The development of the wool industry is largely due to the efforts of the men who provided the cotton manufacturers with machinery. Although wool has been spun and woven for countless centuries, the appliances used altered little in design, until the impetus given to the cotton trade by the inventions of the eighteenth century suggested that similar inventions might be introduced into the wool trade. We have seen how Edmund Cartwright gave the power-loom to the cotton trade, in spite of the fixed belief of the manufacturers that weaving by machinery was impossible. He next turned his attention to wool-combing, and patented a machine in 1790.

Hitherto the tiresome and tedious operation of wool-combing—separating the fibres ready for spinning—had been performed entirely by hand. It took a very long time, and since the supply of wool was



By courtesy of Messrs Horrockses Crewdson & Co

COTTON SPINNING SHED

On the left is a roving frame in which the cotton fibre is wound upon bobbins. On the right are the spinning mules. A single machine has over a thousand spindles, capable of spinning and winding four thousand miles of thread per day

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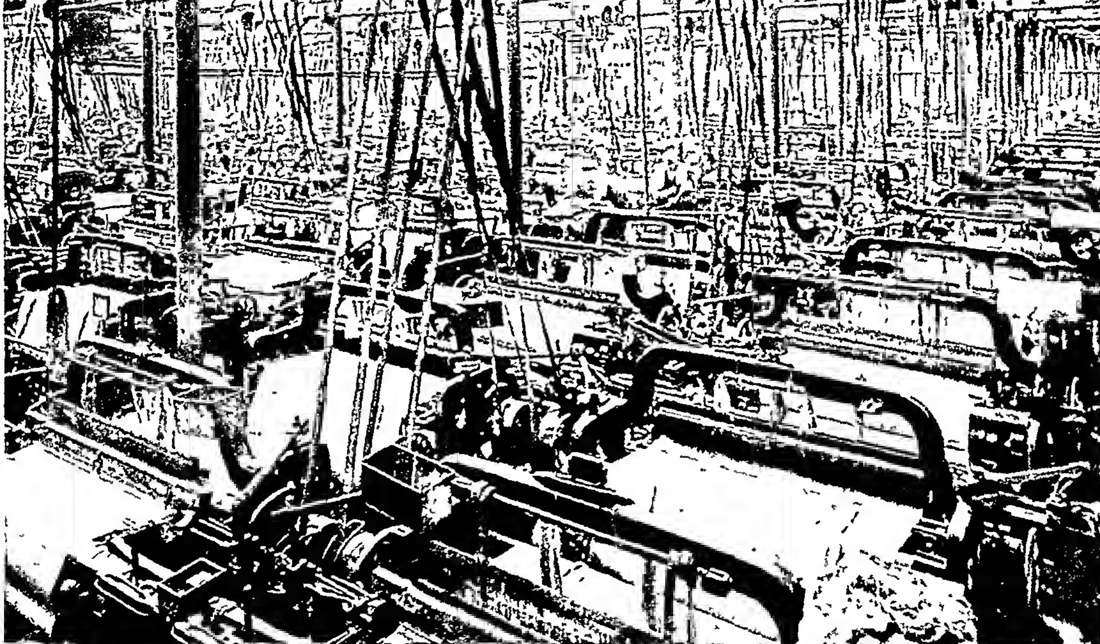

By courtesy of Messrs Horrockses, Crewdson & Co

COTTON WEAVING SHED

Long avenues of looms in one of the largest weaving factories in England As the cloth is woven it is wound on rollers

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increasing rapidly owing to the improvement in sheep rearing and breeding, there were not enough wool-combers to do the work. Cartwright patented his perfected machine in 1792, and named it Big Ben. The power was supplied by a horse turning a shaft, and the machine was eminently useful for working the coarser kinds of wool, but not successful with the finer kinds.

During succeeding years many other patents for wool-combing machines were taken out, including those of the same Mr. Lister (afterwards Lord Masham) who did so much for the silk trade. The wonderful machines of the present day, which shake out the locks of wool, scour them, wash them, free them from burrs and other foreign substances, and finally spin the long threads into yarn, have grown out of simpler appliances, in the amazing way in which machines of all kinds have grown within the last seventy years. Then there are felting machines and weaving machines, and horrible machines which seem to be all teeth, and tear rags and pieces of all kinds—known as *mungo*—into fragments to be re-felted and sold as shoddy.

To find the beginning of the silk trade we have to go back ages into the past, among that wonderful nation whose people we refer to contemptuously as "heathen Chinees". There can hardly exist a boy who has never kept silk-worms, but it is highly probable that few boys realize that in keeping silk-worms they are following the illustrious example of

a lady named Se-ling-She, wife of the Emperor Hwang-te. It is believed that the first silk-worms to be cultivated were taken to China from the Himalayas, where several kinds abound in the forests. But no particular interest was taken in the making of silk, or at any rate no record exists of any importance being given to the industry, until 2640 B.C. In that year, the Chinese historians assert, Queen Se-ling-She instituted the culture of silk-worms, attending to the little creatures herself. She it was, presumably, who devised the method of reeling the cocoon without damaging the thread, and she is credited also with the invention of a loom. Inspired by her success, her husband designed garments to be made from the silk she wove, and it is possible that this accounts for the wide, straight dress worn by the Chinese from time immemorial. A mere man could have had little regard for the niceties of "cutting out" and "fitting", so dear to the heart of the milliner of to-day. Hwang-te probably had himself measured up and down and across, and then had the silk cut to the required length, and straight pieces joined on to make his robe the right width. However that may be, the silk industry received an impetus in China which it has never lost.

For centuries the whole process was kept a profound secret, and the other civilized countries of the world all had to send to China for silk. In fact, the word China is derived from an ancient root signifying "silk". It was the silk country. Many legends

have sprung up to account for the discovery of the mystery and the spread of the industry amongst other peoples, none of which can be wholly believed. One story says that an Indian prince, on a visit to the Chinese Emperor, fell in love with one of the princesses, and they were married. The bride had a sumptuous dowry, but in her head-dress she concealed some silk-worm eggs, which proved the most valuable of all the riches she brought her husband.

Putting legend on one side, the accepted story is sufficiently fascinating. Two Persian monks journeyed to China to carry the message of the Faith, and while there they became acquainted with all the details relating to the care of the silk-worm and the manufacture of silk. At length they were able to steal some eggs, which they hid in a hollow cane. After many dangers and hardships they got safely out of the country with their treasure, and made their way to Constantinople—no mean journey in the year 550—and laid their case before the Emperor Justinian. By the Emperor's wish the industry was started, and was soon on the way to prosperity.

All this time, and for centuries to follow, silk-making was carried on by hand with the aid of the simplest of apparatus. A little wooden contrivance for winding the silk and a loom were all that was needed. But the great silk factories of mediæval Europe produced vast quantities of beautiful silken stuffs, by methods which were guarded as jealously as the Chinese process had been. We know how, after

the revocation of the Edict of Nantes, many French workmen sought refuge in England, and taught, amongst other things, their own methods of manufacturing silk. In spite of this assistance, however, England remained far behind in the silk industry, Italy producing the best work of all European countries. She was at length forced to give up her secrets through the daring of a manufacturer of Derbyshire named John Lombe. In the disguise of a common workman, Lombe went to Piedmont and obtained a post in one of the leading factories there. For some years he worked hard with his hands, and harder still with his ears and eyes. Then, when he had learnt all he could, he made his escape and returned to England. On the banks of the River Derwent he built a large factory, fitted with machinery copied from the Italian, and worked by water power. Unfortunately he did not live to enjoy the fruits of his enterprise, for his Italian enemies found him out and poisoned him. But his factory was taken over by a relative of his; and thus, in the first half of the eighteenth century, the manufacture of silk goods by machinery was inaugurated in Great Britain. Lombe's factory was the first of many, and the great centres of the silk industry in Lancashire and Cheshire owe their existence to him.

One of the greatest problems which the silk manufacturer had to face in bygone days was the utilization of waste. A certain amount of flossy substance is always reeled off with the silk, and it was regarded

as impossible to spin this floss into thread. As long ago as 1671 a patent was taken out by Edmund Blood, who believed that the waste might be used if it could be carded by teasels or roving-cards. Nothing was done, however, with the appliance he patented; in fact, nothing was done with the matter at all until the nineteenth century, when a manufacturer of Bradford named Lister, who was afterwards created Lord Masham, perfected a process for spinning the waste. The silk obtained from the waste is known as "spun" silk and is about half the price of "thrown" silk, as the finest product is called.

Hardly less wonderful than the actual making of silk goods are the means used to adulterate them. It is undeniably a fact that most manufactured articles are adulterated in some way or another, and silk lends itself particularly well to treatment of different kinds. It has a capacity for absorbing large quantities of water, and in this way it is possible to make it absorb metals in solution. Silk thus loaded with tin, or some other metal, appears very heavy and lustrous, but it is the metal which gives it weight and brilliance, the silk itself being of the poorest quality. But this very questionable trick of the trade is defeating its own ends, for people are learning to recognize the loaded silk and to buy in preference the beautiful artificial silk, made from wood pulp and vegetable fibres, which the chemist has put within our reach.

After all is said and done, however, the invention which has done most for silk-worm culture and

the manufacture of silk is not a machine at all. It plays no part in reeling, teasing, spinning, or dyeing the silk, nor in weaving or printing it. Its use is concerned solely with the worm itself, and as an invention it has no place in this chapter; yet its application to this particular purpose has been the means of saving the silk culture in many countries where it had nearly failed. I allude simply to the microscope.

Silk-worms are liable to many severe diseases, some of which are highly infectious. Before people began to apply science and the microscope to silk-worms, it was no infrequent thing for an entire colony to be wiped out in the space of a day, and even the less dangerous epidemics might account for many worms before the infected area could be ascertained. It was these devastating diseases which killed the silk-worm culture of France, and caused that of Italy to dwindle and decay. It was not until M. Pasteur, who did so much for the diseases of mankind, turned his attention to silk-worm plagues, that any means of dealing with them was found. Nowadays the eggs and the worms are subjected to the closest microscopic inspection, and any which are found to be infected are destroyed immediately.

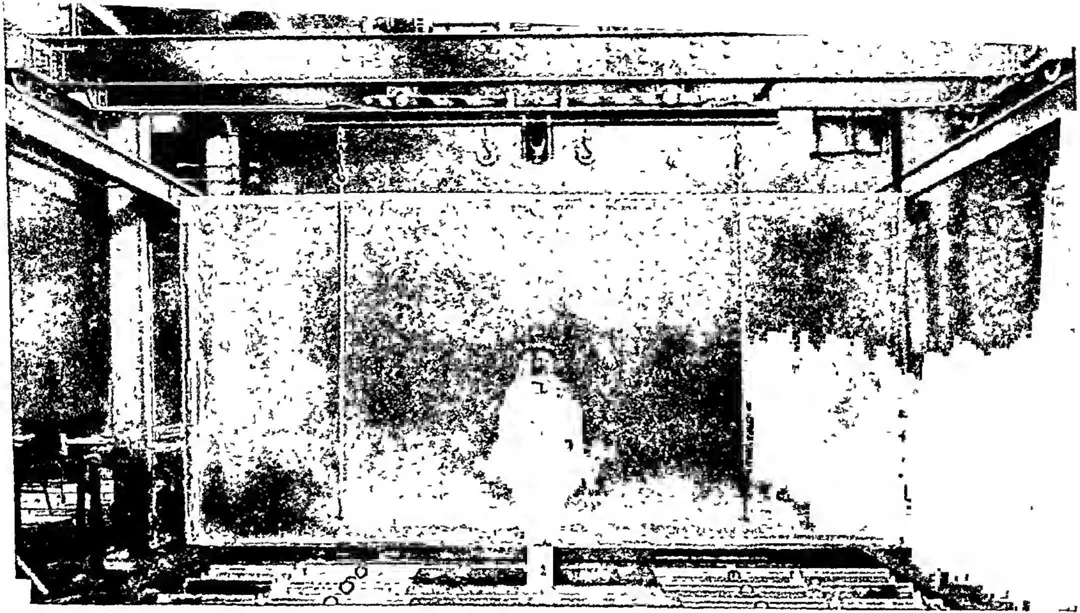
Apart from the huge and complex machines which spin yarn and weave cloth, there is another kind of machine upon which we depend for cheap clothing. Whether your mother makes your shirts at home or buys them ready-made at a shop, you may be sure

that the invention of Elias Howe has entered into the business. Machines for coarse sewing were made in the eighteenth century, but the handy instrument which we generally mean when we refer to a sewing-machine was patented in 1846. Elias Howe was the son of a small farmer in Massachusetts, and was employed in a factory for making cotton machines. Here he acquired a considerable mechanical knowledge, but wretchedly small pay, and it was principally with the idea of making money that he devoted himself to the construction of a machine which should do the work of a seamstress. After years of toil he had mastered every difficulty but one, and that one seemed insuperable. In theory the machine was all that could be desired, but practice told a different tale. The machine would not sew, and a sewing-machine that will not sew is about as useful as a cup without a bottom. Try as he would, he could not find the cause of the trouble. Everyone has heard the story of how, worn out and utterly disheartened, Howe fell asleep one night in the garret where he worked, and dreamed that he was condemned to die because he could not perfect his machine, and that the guards who led him out to die had their spears pierced at the points. Waking, he knew at once that the way was clear before him, and that if he pierced his needle at the point instead of at the head, his machine would do all that was required.

Nowadays America is a kind of natural breeding-ground for labour-saving devices of all kinds, but in

those days things were different, and nobody wanted Howe's sewing-machine. Neglected in his own country, he sailed to England, where he sold the rights for £250, and adapted his machine to the purposes of corset-making. But luck was against him, and in 1849 he managed to borrow enough money to take him back to his dying young wife, to find that while she had succumbed to the effects of privation and poverty, others had stolen his idea and were making huge profits from it. The possibility of fighting and defeating his enemies brought Howe a valuable distraction at this sad time, and, though he was almost penniless, he somehow accomplished the difficult task. The law upheld his claim to the invention, and for the next thirteen years, the remaining term of the patent, all makers of sewing-machines were obliged to pay Howe a licence. In these years he reaped a huge fortune, as he deserved.

It is impossible to mention all the descendants of Howe's clumsy machine and the machines made in the eighteenth century for rough-tacking and sewing leather. Every article of clothing we wear may be made by machine; the finest of lace and raised embroidery, fancy stitchings of all kinds, mackintoshes or heavy overcoats, boots or knitted stockings—somewhere there are factories full of machines making all these and every other garment you can think of. Hand work of all kinds can be imitated more or less successfully by machine, whether it be knitting, crotchet, embroidery, or drawn-thread work. In fact,



A PLATE OF ARTIFICIAL ICE WEIGHING FIVE TONS

The clearness of the ice can be judged by the fact that a man is seen standing on the other side of the plate, which is 12in thick. The photograph was kindly lent by The Lightfoot Refrigeration Company, Ltd

Page [illegible]

plain sewing by hand has gone out of fashion entirely, except for very fine garments for women and children, machine-stitching being regarded as both stronger and more ornamental.

This is becoming a very long chapter, but as a matter of fact there are still many machines, which help to cover our nakedness and protect us from the weather, which have not been described. Hat-making, boot-making, glove-making, button-making, all have their special machines, as do the industries devoted to furs, feathers, artificial flowers, and trimmings of all

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vainly to the chemists for help. As a matter of fact, the problem was solved by Professor Hummel in 1858, but he did not recognize the value of his discovery. He was looking for a new method of dyeing, not waterproofing, but without knowing it he hit upon the very process the tanners were praying for. In course of time this process was rediscovered, unfortunately by an American, Augustus Schultz, who took out a patent for his invention. In this way British tanners lost the start they might have had. By the new method leather was submitted to a chrome preparation which rendered it waterproof without the tedious waiting necessary in the old method of tanning.

This, however, is not the end of the story. Finding leather was cheap, the enterprising American manufacturer flooded the market with boot-making machinery, and at a particularly happy time. The Civil War had just broken out, and hundreds of thousands of pairs of boots were wanted by both sides. Hand work could never have supplied the demand, but machine work could—and did. Not content with his success at home, the American sent his machines across the Atlantic, and the British boot-maker received the worst blow of his life.

The machinery used in boot-making is wonderfully ingenious. Every process is done by machine, if not quite as well as by hand, at least well enough for the average purchaser. The leather is first of all passed through a machine which reduces it all to a standard

thickness, and then through another which presses and solidifies it. The various parts are cut out either by knives driven by steam power or by dies operated by a steam-hammer. The sewing and fitting together are likewise done by machine, as are the polishing and trimming-up which finish off the boot.

At first the success of the American machine-made boot was so great that it seemed possible that British boot-making would come to an untimely end. But the tanners had been working along on their same old lines and the chemists had been working on theirs, with the result that Professor Proctor was able to produce an entirely new process of tanning, which was simpler and more efficacious than the American, at about the same time that British manufacturers produced machines of their own. The virtues of the British boot, made of British leather, had only to be tried to be appreciated, and once more Great Britain took front place as a boot producer, a place which she proudly holds to-day.

Straw-hat making hardly has a place in this chapter, as it is done by hand almost entirely, and yet it owes much to man's inventive and experimental instincts. Straw hats have been in use for centuries, but it was not until the reign of George I that any changes in their manufacture were introduced. Previously the whole wheat-straw had been used, but at that time it was found that the pipes might be split up into several pieces with excellent results. A sharp-pointed instru-

by each, and everything connected with the science has, or ought to have, its own name. A system of names like this may be compared to staircases and lifts and passages which make us able to get easily from one part of the house of science to another. I said just now that science is exact knowledge. To have exact knowledge about anything it is generally necessary to be able to measure or count it. The scientific man is always asking such questions as—how long? how heavy? how many? and, like the baby in the soap advertisement, he is not happy till he gets the information he asks for. Now in this chapter I intend to talk about some of the many inventions for measuring, counting, weighing, and so on, and as measurement is the very soul of science, such inventions are scientific in a very special sense. After all, I think there is nothing wrong with the name of this chapter.

Perhaps the simplest kind of measurement is that of length. At first sight it seems very easy to find out how long a thing is, or how far two points are apart. If no very great accuracy is required, the matter is simple enough. A man gets an idea of the length of a lawn by pacing it, a carpenter measures a plank with his two-foot rule and tells you the length in less than a minute. But it is a very difficult thing to measure a length really accurately, and the more exact we want to be the more difficulties crop up. First, we must decide what length it is that has to be measured, where we are to begin and leave off. Take the case

of the lawn as a rough example. You are going to measure from the flower-bed at one end to the gravel path at the other, but when you come to look closely you see that it is not easy to say exactly where the ends are. The edges are not quite sharp. Of course, we do not have to worry about the hundredth of an inch when it is a lawn we are measuring, but in the length of a piece of metal that is to be part of an aeroplane, and still more in the case of one of the parts of a delicate piece of electrical apparatus, to be a hundredth of an inch out would be fatal. Then, even from a practical point of view, suppose that some parts of a machine are made in Glasgow and others in Birmingham. However careful the Glasgow and Birmingham manufacturers may be, the whole business will go wrong if the measuring tools in the two places do not quite agree, if what the Glasgow people reckon to be a foot is just a little longer or shorter than a foot according to the Birmingham standard.

However exact measurements have to be for manufacturing purposes, measurements for pure science must be still more exact. It is most necessary that, in every laboratory, what are supposed to be the same standard measures of length and other quantities should be really the same. For ordinary trade purposes inspectors of weights and measures go round, and their tests keep the weights and measures nearly enough alike in all parts of the country. But something more is required for scientific purposes, and in most civilized countries there are central laboratories,

generally under Government control, a large part of whose work consists in keeping up the standards of various kinds to the highest possible degree of accuracy, and testing the copies of these that are to be used for exact measurements throughout the country. In the United States there is a very large and important Bureau of Standards, in France a National Laboratory, and we have had in England, since 1901, a "National Physical Laboratory" which does the kind of work I have mentioned and much else besides.

You cannot measure anything unless you have a unit suitable for that particular kind of thing. Lengths must be measured in length-units, time in time-units, speeds in speed-units, and so on. That there may be no doubt as to what the unit really is, there must be some authority to settle it and appoint a standard. Sometimes the authority is the Government of a country. We have, for example, in England a particular metal bar the distance between two points on which has been declared to be the standard yard, and a lump of metal the weight of which is the standard pound, both by Act of Parliament. Other units and standards are settled by committees of scientific men, either of one nation, or sometimes of all civilized countries. For pure science there is a general agreement as to the chief units, which serve as the foundation of nearly all the others—the centimetre for length, the gramme for weight (or, more strictly, for mass), and the second for time. The units used by electrical engineers, such as the ampere and volt, are con-

nected in a very interesting way—which I must not stop to explain—with these three fundamental units.

One of the reasons why, as I said before, length measurements are so important is that length comes in so many other kinds of measurement. Take the case of speed or velocities. Suppose we want to find out at what rate sound travels, or the velocity with which a shell leaves the muzzle of a big gun, we shall have to measure a length and a time, just as you would find out how fast a boy can run by timing him over a measured distance. There are many devices used in measuring lengths. The vernier is a little scale that slides along the edge of a bigger scale. The marks or graduations on the vernier are a little closer together than those on the main scale—ten divisions of the vernier generally equal nine on the scale. If this is in inches divided into tenths, the vernier enables you to read lengths to a hundredth of an inch. For still greater accuracy, use is made of fine screws. The thread is very carefully cut, so that each time the head is turned round once, the screw travels forwards or backwards perhaps a millimetre, which is about $\frac{1}{25}$th of an inch. By making the head of the screw a large circle divided round the edge into 100 equal parts, we can measure small lengths to the nearest $\frac{1}{2500}$th of an inch. Another very accurate way of measuring lengths is by a travelling microscope; in this, also, fine screws are used.

Many distances are too large or too small to be measured in a straightforward way. In such cases

we often measure some other distance that has some known proportion to the one we really want to find out. Here mathematics comes to the help of science. We find it stated in our geography books that the earth is so many miles in diameter, that the top of some mountain no one has ever climbed is so many feet above sea-level, or that the Dead Sea is so many feet below it. All these distances are found by a combination of actual measurements and calculations. The measurements required for map-making, for geography generally, and for astronomy are partly direct measurements of length and partly measurements of angles. You know that the study of triangles, squares, circles, and so on is called geometry, and this really means earth-measurement. The science of geometry began—as most, if not all, sciences began—by men wanting to know something for a practical purpose. Originally it was taken up because it was found useful for what we should now call land-surveying. Some boys like geometry; others do not, and are apt to ask what good it is. Without geometry, and what it has led to, we should have a very poor chance of getting any breakfast to-morrow morning. No geometry, no maps, and no charts of the ocean; no charts, no ships could come and bring food to England from almost all parts of the earth. The very worst that submarines could ever do against us would be but a trifle to what we should lose if geometry and all that it has made possible were suddenly done away with.

The theodolite of the land-surveyor, the sextant of the ship captain, the prismatic compass of the scout-master, are all instruments for measuring angles. Instruments of wonderful precision are in use at Greenwich and other observatories, and it is possible with some of them to measure to a fraction of a second of arc. Think what this means. There are 60 seconds of arc in a minute, 60 minutes in a degree, and 90 degrees in a right angle. Suppose a triangle having a base of an inch and two equal sides each 1432 yards long. The angle opposite the base would be one second. In the astronomical instruments for measuring angles, the devices I have already mentioned, such as the micrometer screw, the vernier, and the travelling microscope, all come in. The astronomer's calculations of distances run into millions of miles; in fact, he tells us that the nearest of all the fixed stars is 25 billions of miles away from us, and it seems curious that in order to find such a number as that, he has to adjust a spider thread and measure the distance he moves it to the ten-thousandth of an inch. The possibility of making these and other delicate measurements depends upon having accurately-divided instruments. The invention of the dividing engine was a very important one. There are two forms of it, the linear and the circular. The linear engine is used for dividing a straight line into any number of equal parts, and the circular for making marks at equal distances around the circumference of a circle. By means of a dividing engine and a fine diamond point, lines can be

ruled upon a piece of glass so that there are as many as, or even more than, 40,000 to the inch. When the lines are as close as this, a powerful microscope is required to see them. I mention the ruled plates because they can be used for determining the wave-length of light. This is different for different colours, but always exceedingly small, yet there are several ways in which the wave-lengths can be found very accurately indeed. One of the most exact of all these measurements showed that for a certain kind of red light there are 1,553,163½ wave-lengths in a distance of one metre, so that each is about $\frac{1}{25000}$th of an inch. So you see that science is not afraid to tackle the toughest problems in lengths and distances. One man is measuring the distances of stars, and thinks in billions of miles; another measures the wave-length of light, and thinks in ten-thousandths of an inch. Even this is not the limit of smallness. It is known that the diameter of a chemical molecule is much smaller than these wave-lengths, that atoms are smaller than molecules, and that the atom is a giant compared with the electron or electrical corpuscle.

The balance, or scales for weighing, must be a very ancient invention. It is often mentioned in the Bible, and it seems that in those early days there were dishonest people who had false balances and unjust weights. When we weigh anything, for instance a piece of silver, what is it we do, and what do we do it for? We have certain lumps of metal called "weights", and we find that a certain set of these just

balances our piece of silver. They have the same weight; that is, the earth attracts them both to just the same extent. We compare two pulls and find them equal. But we do not, as a rule, care much about the pull of the earth on our piece of silver. What we really want to know is—how much silver is there in the piece? It is quantity of stuff or matter that we are interested in, and this is what is meant by mass. Things having equal weights at the same place have equal masses. Weight and mass are not the same thing; *one is a force, the other, quantity of stuff*; but as they are at the same place proportional to each other, we often say weight when we mean mass.

The best balances are very exact and delicate instruments, most beautifully constructed. The beam has a wedge of agate, pointing downwards, in the middle, and one at each end, where the pans hang, pointing upwards. When in use these knife-edges work on flat or curved pieces of agate called planes. When not in use the knife-edges do not touch the planes, but by turning a handle they can be brought into contact, and the balance put into action. To the beam is attached a long pointer, and this moves in front of an engraved ivory scale. By looking through a little microscope you can see just how far each side of the centre the pointer swings. The more delicate the balance the more difficult it is to use. The whole thing is in a glass case, and there is an arrangement for finishing the adjustment of the weights without opening the case. The slightest draught would be

fatal, and the shelf or table on which the balance stands must be very firm, and not liable to vibration. With a first-class balance properly used it is possible to weigh a body of about one pound correctly to one ten-millionth. Professor Boys discovered a way of making quartz or rock crystal into very fine threads. Two pieces are pressed together, and a very hot blowpipe flame plays on the parts that touch. The quartz gets soft, and the pieces stick together. One of them is attached to a kind of arrow that can be shot away by a crossbow, and this is done when the quartz has got soft enough. The piece flies off, but, as it flies, it pulls out a long and very fine thread of the softened quartz. These fibres are used for many purposes, and especially for measuring very small forces. If a fibre is hung up by one end and has a little bar attached to the other, a very small force acting on the bar will cause a twist in the fibre. The amount of the force can be calculated from the amount of the twist. Such an instrument is called a torsion balance. Boys did not invent the balance, for it has been known a long time, but he greatly improved it by using his quartz fibres instead of wires.

It may seem scarcely credible that such an apparatus can help us to find the weight of the earth, but it can. A little leaden ball is put at each end of a light rod hanging at right angles to the fibre. Large leaden balls are brought near the little ones, so that the attraction which, according to Newton, every piece of matter exerts on every other piece shall come into play. From

By courtesy of the Agent General for New South Wales

SHEARING SHEEP BY MACHINERY, NEW SOUTH WALES

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the amount of twist, the attraction on each of the little balls can be calculated, and then compared with the weight of the ball, that is, with the force with which the earth attracts it. After making allowance for the fact that the centre of the big leaden ball is only a few inches from the little ball, whilst the centre of the earth is about 4000 miles away, we can compare the amount of matter in the earth with that in the big ball, and work out the answer in tons. This is what is meant by weighing the earth. When the astronomer knows the weight, or more correctly the mass, of the earth, he can calculate the masses of the sun, moon, and planets. Here again we have an example of the measurement of something very small helping us to measure something very big. Although the ordinary balance is generally used for comparing weights, and so masses, with each other it can also be used for measuring other forces by balancing them against weights.

There is a beautiful instrument at the National Physical Laboratory for weighing the attraction between electric currents flowing in parallel coils of wire. This is called the ampere balance, and is one of a set of instruments used for fixing exact standards of electrical units, so that electricians of all countries may mean exactly the same thing when they speak of amperes, or volts, or ohms. This is as important as that there should be uniformity in the standards of length or time. Time is measured, as we all know, by clocks and watches, and when these are of the highest

possible accuracy they are called astronomical clocks and chronometers. For a chronometer to measure time as exactly as a good balance measures weight, it must not be liable to lose or gain more than three seconds in a year. For many time measurements we want to be able to reckon to the hundredth or thousandth of a second. Suppose a tuning-fork has a little mirror attached to it, and that a beam of light falls on this and is reflected through a narrow slit on to a photographic plate sliding downwards behind the slit. The light leaves its trace on the plate—a straight line if the mirror is at rest, but a wavy line when the tuning-fork is sounding and moving the mirror. If the tuning-fork vibrates 1000 times a second, every peak in the curved line will represent $\frac{1}{1000}$th of a second. This particular kind of chronograph, as such instruments are called, is used at the National Physical Laboratory for testing the speeds of photographic shutters. The shutter is put between the mirror and the slit, and as long as it is closed no light gets through and no mark is made on the plate. When the shutter opens, the mark begins; when it is closed again, the mark ends. To find how long the shutter was open it is only necessary to count the peaks on the bit of wavy line. There are many other kinds of chronographs. Some do not use photography, but a mark is made by a bristle on smoked paper, or by a little inked brush on white paper. But in nearly all, the something that makes the marks and the something that has the marks made on it move in two

directions at right angles. Electricity is often pressed into the service of the chronograph to record the beginning and the end of the time interval to be measured. When we can measure lengths and times we can measure speeds or velocities. When we hear of a motorist or bicyclist being fined for exceeding the speed-limit, we know that a policeman must have measured the velocity of the car or bicycle by noting how long it took to travel over a known distance.

Although we usually speak of thunder and lightning instead of lightning and thunder, yet we see the lightning before we hear the thunder. The sound, travelling through and by means of the air, takes longer to get to us than the light, travelling by means of the ether. Of course, the light has to come through the air, but the air does not help it. When it is snowing hard we may have to walk through it, but we do not get to our journey's end any the sooner. The rate at which sound travels through air can be found quite easily. The simplest plan is by firing a cannon. A man, two or three miles away, notes the exact moments at which he sees the flash and hears the report. Suppose the difference in time is ten seconds and the exact distance is 11,000 feet, then the speed of sound is 1100 feet in a second. In more accurate experiments an electric chronograph is used, and the instants at which the cannon is fired and the sound reaches a place a known distance off, both record themselves. The speed of sound is greater in

warm air than in cold; in water it travels faster than in air, and faster still in iron. Although the velocity of sound is so easily measured, the case of light is very different.

The first measurements were astronomical, and made by watching the eclipses of one of the moons of Jupiter. Sometimes we are about 184 million miles nearer to Jupiter than at other times, so that when we are farthest away the light has that much farther to travel, and this takes about eighteen minutes longer than when we are nearest. Light from the sun takes about eight minutes to get to us, so that we do not see the sun as it is at the instant we are looking at it, but as it was eight minutes earlier. It is just like receiving a post card from a friend. He tells you, perhaps, that he has just climbed a mountain and is writing the post card at the top, but by the time you get the card he is probably somewhere else and doing something different.

Besides the astronomical ways of measuring the speed of light there are others, and I will try to give an idea of one of them. In some towns, for example Poole in Dorset, the railway actually crosses the street. When a train is coming a gate is shut, and traffic on the road is stopped until the train has passed and the gate opens again. Let us suppose that this happens so that the gate is open for five minutes, shut for five minutes, and so on regularly. A man on horseback rides through when the gate is just open, goes half a mile up the street and back again, and

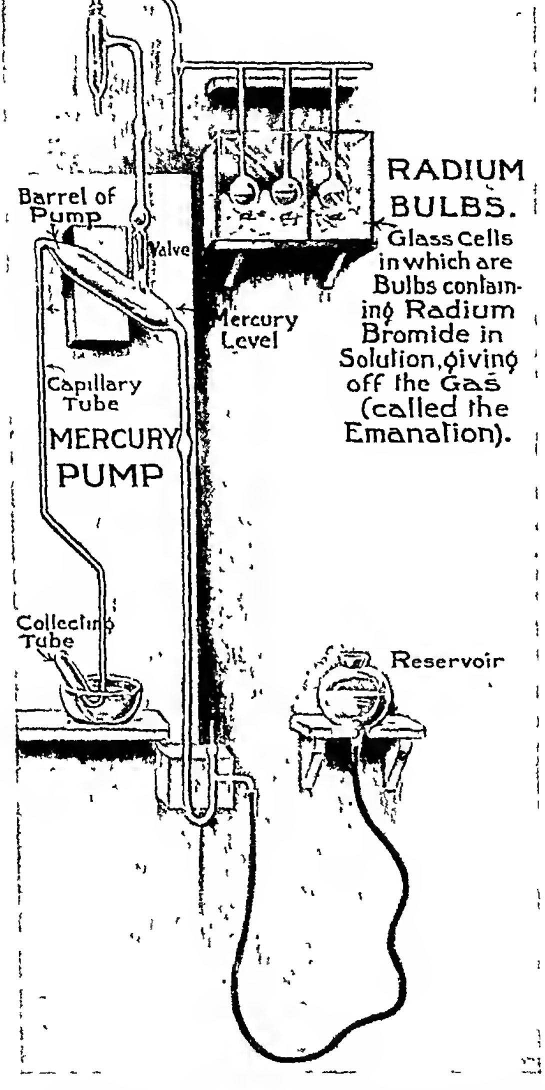
just gets through before the gate closes. What is the speed of the horse? Evidently twelve miles an hour, for it has gone half a mile each way or a mile altogether in five minutes. Now in the celebrated experiment of Fizeau we have a beam of light instead of the horse, and the place of the gate that opens and shuts is taken by a wheel having teeth along its edge, each tooth being of the same width as the gap between two teeth. The wheel turned round quickly, and had 720 teeth, and of course an equal number of spaces. The light was sent between two teeth to a mirror rather more than five miles away. The mirror sent the beam straight back again. If the wheel had turned through the width of a tooth while the light was travelling the ten miles, the gate was shut and it could not get back. The gate on the railway was supposed to be opened for five minutes at a time, but in the experiment the wheel turned so quickly that the light had only about $\frac{1}{1800}$th of a second to do the double journey and get back before it was too late. This short time was just enough, showing that light travels at the immense speed of more than 180,000 miles in a second. The experiment has been repeated with various improvements, and another and still more accurate method has been invented and used. We now know for certain that the speed of light is just about 186,500 miles, or 300,000 kilometres, per second. This distance is about seven and a half times the circumference of the earth. Great as is the speed of light, the distances of the stars are so enormous that

light takes some years to travel to us, even from the nearest of them.

For military purposes it is desirable to know how fast shells and other projectiles travel, and, in the science of gunnery, determinations of the muzzle velocity, or the speed at which the projectile leaves the gun, are very important. Here again electric chronographs are used. These velocities are, of course, different according to the size of the gun and the charge of powder or other explosive used. Besides, unlike the velocity of light or sound, the velocity of the projectile grows less as it forces its way through the air. When it leaves the gun the shell often travels much faster than sound, so that at first it keeps ahead; but the sound, like the tortoise in the fable, may pass it later on if the range is very great. Sound and light are each due to a kind of wave-motion, but there are many other kinds, water-waves for instance. The speed with which these travel has been much studied, and, without going far into the matter, I may mention one or two interesting facts. One is that the velocity is not the same for all water-waves—it depends on the wave-length, that is, the distance between crest and crest or hollow and hollow. When this is a little less than $\frac{3}{4}$ inch, .71 inch to be more exact, the velocity is as small as it can be, $9\frac{1}{3}$ inches per second. Little ripples travel faster than this, and so do longer waves. Waves in the Atlantic are sometimes more than 500 feet from crest to crest, and between 40 and 50 feet high. Such waves have been observed to

travel at a rate of about 40 feet per second, or twenty-seven miles an hour. Waves may travel in the solid earth as well as in the water of the sea. Slight and gentle ones are very frequent, and, as a rule, no notice is taken of them, as they cannot be detected without special instruments. But sometimes large and violent waves are set up, and these cause the earthquakes which may destroy cities and be felt over an entire continent and in the ocean around it. Earthquake waves do not all travel at the same rate even when they move across the same country; the speed seems to vary from a few hundred to several thousand feet a second. In other words, the speed is sometimes less than that of sound in air and sometimes as much as eight times as great. The late Dr. Milne was one of the chief authorities on this interesting subject. His earthquake observatory at Shide, in the Isle of Wight, was fitted with a number of instruments, some of them invented by himself, for detecting even the smallest earth movements. Such instruments are called seismoscopes, seismometers, and seismographs. The first simply show that there is an earth movement, the second measure it, the third make a record of it. You may think that it was not much good having an observatory in the Isle of Wight, because, you may say, we do not get earthquakes here. We do, however, get a good many on a very small scale, and Dr. Milne found that a great earthquake occurring almost anywhere in the world made some impression on his instruments at Shide.

When sound passes through air it is only a particular kind of movement that travels, but in winds the air itself moves bodily forward. Instruments for measuring the velocity of the wind are called anemometers, and the same name is given to those which measure its pressure. Robinson's velocity instrument has four cups fixed to the arms of a kind of windmill, and it has dials much like those of a gas meter, which keep count of the number of revolutions. For 500 of these a mile of wind has to pass over the instrument. From this kind of anemometer we can easily find the average velocity of the wind during a given time; but it tells us nothing about sudden gusts, and it is these which blow down trees and do damage all around. In Osler's anemometer the force of the wind drives a metal plate back on springs behind it, and thus moves a pencil, which marks a piece of paper kept in constant motion by clockwork. So the wind is made to keep a kind of diary of its own force, and from this can be read off the amount of the force at any minute. For a perfectly steady wind the pencil traces a straight line, but every gust and every lull, however short, cause the line to be wavy. A breeze is anything up to seven miles an hour, forty miles is a gale, and a hurricane, destroying everything in its path, may move at a hundred or a hundred and fifty miles an hour. The pressure or force is not in simple proportion to the speed, but increases much faster. A wind at five miles an hour gives only about 3 ounces pressure to the square foot, but a hurricane at a



CATCHING THE EMANATION FROM RADIUM

Part of the apparatus for catching the emanation from radium and collecting it in tubes for transportation Radium gives off an emanation constantly, yet itself is not destroyed This emanation has exactly the same properties as pure radium for curative purposes

hundred miles an hour would exert a pressure of 50 pounds on the same area. I shall only mention one other kind of speed measurement. If you happen to tread on a tack and prick your toe, your foot moves before you feel the pain. Some kind of message travels up the proper nerve from your toe to the central office in your brain, and a return message is flashed back again giving orders to the muscles to move the foot. We do not know exactly how the nerves transmit the messages, or nervous impulses as they are called, but it has been found possible to measure the rate at which they travel. It is much smaller than we might have expected, not more than about a hundred feet a second, less than a tenth of the speed of sound in air. If this is about the same for all animals, when a whale 100 feet long happens to hurt his tail it will be a second before the information reaches its brain. Some time—very short, no doubt—will be taken for the message to be decoded, as telegraphists say, and then the return message will take another second in getting to the tail.

From velocity let us turn to heat. The common thermometer is one of a large class of instruments for measuring temperature. Its principle is very simple and easily understood. A glass tube of fine bore has a bulb at the lower end, and inside there is enough mercury to fill the bulb and to reach part of the way up the tube at ordinary temperatures. When it gets colder the mercury shrinks or contracts, and the top of the column falls; when it gets warmer the mercury

expands and rises in the tube. Fixed to the side of the tube or engraved on the glass is a scale of degrees. The two standard temperatures or fixed points are the freezing- and boiling-points of water. There are two principal systems of reckoning temperatures. The Fahrenheit scale marks freezing-point as 32° and boiling-point as 212°; the Centigrade calls these 0° and 100° respectively. It is easy to see that a Fahrenheit degree is only $\frac{5}{9}$ of a Centigrade one. In the great cold of the Arctic and Antarctic regions mercury thermometers are of no use. The mercury freezes to a solid bullet. This happened, for instance, to the mercury thermometers which the great explorer, Dr. Nansen, took with him in his crossing of Greenland. For low temperatures such as these, alcohol can be used, as it does not freeze till it is cooled far below any temperature the explorer finds. On the other hand, alcohol is no good for high temperatures; it would boil and burst the thermometer. Other special purposes require special instruments. There are, for example, several kinds of maximum and minimum thermometers which keep count of the highest and lowest temperatures reached since the instruments were last examined. If you wanted to know what was the greatest outdoor cold during the night, and had nothing but an ordinary thermometer, you would have to keep awake and watch it. It would not be pleasant to spend a long winter's night out of doors. Using a minimum thermometer, you can go comfortably to bed, and in the morning a little index in

the tube tells you what you want to know. The little clinical thermometers which doctors use are a special kind of maximum thermometer. Put into the mouth of the patient, the mercury rises in a minute or so to the temperature of the body, and keeps a record of it which the doctor or nurse can read after the thermometer has been taken out. A rinse and a shake put it ready for use again. It is very important that clinical thermometers should be accurate; if their readings are not correct, the doctor may be led astray in his judgment of the case. Part of the work of the National Physical Laboratory is the examination of these and other thermometers. For instance, all the clinical thermometers used in the navy go to be checked, and the Serbian Relief Committee sent a large batch. During the last six years more than 96,000 clinical thermometers have been tested at the National Physical Laboratory.

Mercury and alcohol thermometers would be no use at all for very high temperatures, such as those inside furnaces, or for very low ones, like that of liquid air. Pyrometers, literally fire measurers, used for great heats, are of many kinds. Wedgwood, the famous potter, invented one which depended on the contraction of baked clay when placed in a furnace, and at the Sèvres porcelain factory the expansion of an iron bar was made use of for the same purpose. Neither of these was very satisfactory, and air thermometers were introduced for the purpose. But the most interesting instruments for measuring extreme degrees

both of heat and cold are electrical. In the chapter on "Electrical Inventions" it is said that when a current of electricity flows through a wire there is a resistance which is greater for a long wire than for a short one, and for a thin one than for a thick one. It is also greater for a hot wire than for a cold one. Now electrical resistance can be measured very accurately indeed, and Professor Callendar has invented a platinum resistance-thermometer which can measure temperatures of over 1800° F. to within a fifth of a degree. A long thin platinum wire is wound on a very thin sheet of mica and enclosed in a quartz tube. The resistance of the wire rises and falls with temperature, and as the resistance can be exactly measured, so can the temperature. This kind of thermometer can also be used for very low temperatures, so that the invention is a most important one.

The chapter just mentioned speaks of heat produced by currents; it is also possible to get currents from heat. Imagine a piece of metal bent like a bow, with a wire of a different metal in the place of the string. If the two ends are equally hot or cold nothing happens, but if there is the slightest difference in temperature a current flows. This will also be the case if the wire joining the ends of the bow be cut in the middle, and the cut ends joined up to a very sensitive galvanometer. We not only get the current, but we know we have got it and how strong it is, and so can tell what is the difference of temperature to which it is due. On this principle depends the

action of the thermopile; also of a pyrometer invented by Sir William Roberts-Austen, and used at the Royal Mint for finding the melting-points of metals. Professor Boys has invented a beautiful little instrument called the radio-micrometer. The principle is still the same, but it is applied to measure or detect very minute changes of temperature. With this, as also with another electrical detector of heat, Professor Langley's bolometer, it can be shown that even the moon gives us a little heat. With these instruments variations of about $\frac{1}{500000}$th of a degree can be detected and of $\frac{1}{5000}$th actually measured. Many other kinds of measurement might be described if there were room, such as calorimeters for measuring quantities of heat, and photometers for comparing the light-giving powers of electric and other lamps. But I must leave these, and end the chapter by mentioning an extraordinary scientific triumph in the way of counting.

A few years ago the world was startled by the discovery of radium. This wonderful substance is perpetually shooting off what are called alpha, beta, and gamma rays. The alpha rays are particles carrying electric charges, and when they have lost these charges they are atoms of the gas called helium. Sir E. Rutherford has described no less than four separate ways for counting the number of these atoms which a given weight of radium shoots off every second. Of course, each one is not counted separately. If we wanted to find out how many grains of wheat there are in 1000 tons, we should not

count every grain, but weigh out, say, half a pound, count the grains in this, and then calculate the number in the 1000 tons. It is somewhat the same with the counting of atoms. Not many years ago the atom was considered to be more or less imaginary, convenient to talk about, but not to be taken too seriously. Many chemists felt inclined to doubt whether there really were any such things. Now we know they are real, and, what is more, can actually compute the number of atoms in, for example, a threepenny-piece. I have worked it out, and find that it is represented by 82 followed by twenty noughts. To count out this number one at a time would take the entire population of the old empires of Germany and Austria-Hungary one million years if they counted day and night at the rate of two a second.